Appendix B. Geotechnical Reports

Documents Included:

- **Shannon & Wilson Geotechnical Report Final, 2006**

GEOTECHNICAL INVESTIGATION
POTENTIAL RELOCATION SITES
KIVALINA, ALASKA

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GEOTECHNICAL INVESTIGATION
POTENTIAL RELOCATION SITES
KIVALINA, ALASKA

1.0 INTRODUCTION

This report presents the results of our geotechnical exploration of three potential relocation sites for the community of Kivalina. The three sites include Simiq, Imnakuk Bluff, and Tatchim Isua (Figure 1). The purpose of the explorations is to provide subsurface information that can be used to evaluate the suitability and development requirements of each site for a new town.

The original scope of the investigation consisted of drilling a total of 9 borings with the option of adding or deleting borings based on the conditions encountered during drilling. The proposed drilling program and the actual program completed in the field are summarized for each site in the following table.

SCOPE OF EXPLORATIONS

Site	Proposed Borings	Actual Borings
Simiq	One, 40-foot-deep boring	Two, 20- to 22.5-foot-deep borings
Imnakuk Bluff	Four, 25-foot-deep borings	Four, 23.3- to 26- foot-deep borings
Tatchim Isua	Four, 25-foot-deep borings	Eight, 8.3- to 21- foot-deep borings

At Simiq, two shallower borings were drilled to characterize the different subsurface conditions beneath the patterned (polygonal) ground encountered at the site. At Tatchim Isua, favorable conditions were encountered (i.e., relatively shallow bedrock), and four additional borings were requested by the U.S. Army Corps of Engineers – Alaska District (USACE-AD). One boring at Imnakuk Bluff was drilled to evaluate a potential source of granular material exposed in the bank of the Kivalina River. In addition, a shallow test pit was dug in the bank of the Kivalina River to obtain a sample of the exposed, granular material.

Samples of subsurface materials collected during drilling were returned to our laboratory for examination and index property testing. Based on the results of the field and laboratory work, conclusions were made on the suitability of each site for development, and recommendations were made for general geotechnical design parameters for buildings, unpaved traffic areas, and utilities.

A USACE-AD Statement of Work for this project is located in Appendix E.

2.0 FIELD AND LABORATORY STUDIES

2.1 Field Explorations

A total of fourteen exploratory borings were drilled for this project: two borings at Simiq, four at Imnakuk Bluff, and eight at Tatchim Isua. The borings were drilled to depths ranging from 8.3 to 26.0 feet. In addition, a test pit (TP-05-1) was hand dug in a deposit of outwash gravels exposed in the bank of the Kivalina River at the Imnakuk Bluff site. The purpose of the test pit was to collect a more representative sample of the gravel than could be obtained from the boring.

Boring and test pit numbers, locations and the drilling depths are summarized in the table below and are shown in Figures 2, 3, and 4, for the respective sites. The locations were determined using a hand-held GPS and have an accuracy of about ±20 feet.

Site	Boring/Test Pit Identification	Total Depth (feet)	Latitude	Longitude
Simiq	05-1	22.5	N67.78609	W164.47415
	05-2	20.0	N67.78620	W164.47412
Imnakuk Bluff	05-3	23.3	N67.81076	W164.56284
	05-4	25.4	N67.81570	W164.59783
	05-5	26.0	N67.82088	W164.59229
	05-6	26.0	N67.82279	W164.60881
	TP-05-1(1)	4.0	N67.81055	W164.56329
Tatchim Isua	05-7	8.3	N67.84528	W164.73532
	05-8	13.4	N67.84895	W164.72621
	05-9	8.2	N67.84718	W164.73122
	05-10	21.0	N67.84334	W164.73958
	05-11	10.5	N67.84513	W164.72507
	05-12	8.5	N67.84685	W164.72081
	05-13	15.0	N67.85083	W164.73225
	05-14	14.0	N67.84881	W164.73717

Datum: NAD27
(1) Test Pit

Borings 05-1 through 05-10 were drilled at locations selected by us. Borings 05-11 through 05-14 were additional borings drilled at the general locations as requested by the USACE-AD.

Drilling for this project was completed from July 28 through August 4, 2005. The weather was generally sunny to partly cloudy throughout the duration of the fieldwork, with morning and evening coastal fog and daytime high temperatures ranging from 60º to 70ºF. Frank Wuttig, a geotechnical engineer with our firm, supervised and conducted the fieldwork for this project.

Logs of the subsurface conditions encountered included soil classification according ASTM D 2488 and 2487, frozen ground classification according to ASTM D 4083, frost susceptibility classification according to TM 5-822-5, and boring details on drilling equipment and a summary of selected laboratory test results are shown in Appendix A. Subsurface conditions also described in accordance with Shannon & Wilson's classification systems are presented in Appendix D.

2.2 Drilling Methods

Drilling and sampling were performed by Discovery Drilling, using a modified CME 45 drill rig that could be transported with a helicopter. All three sites required helicopter access. Helicopter services were provided by ERA Aviation, Inc. Weather conditions were generally suitable for flying throughout the duration of the fieldwork, with occasional morning delays due to coastal fog.

The borings were advanced with a combination of 3¼-inch I.D., hollow-stem augers (HSA) and 6-inch solid-stem augers (SSA). As the borings were advanced, samples were generally taken at 2.5-foot intervals to a depth of 10 feet and at 5 feet thereafter. Samples were obtained by driving a 2.5-inch I.D. (inside diameter), split-spoon sampler 18 to 24 inches into the soils at the bottom of the hole with blows of a 340-pound hammer free-falling 30 inches onto the drill rods. A rope and cathead were used to lift and drop the hammer. The number of blows required to advance the sampler the final 12 inches of each 18-inch sample is termed the penetration resistance (also referred to as blow count), which is a measure of the relative consistency of unfrozen fine-grained soils and the relative density of unfrozen granular soils.

Geotechnical samples recovered using the techniques described above were examined and visually classified in the field, sealed in plastic bags, and returned to our laboratory in Fairbanks for testing. When possible, samples of frozen ground were kept in a frozen condition during their transport to the laboratory.

2.3 Laboratory Testing

Samples of subsurface materials collected from the borings and test pit were returned to our laboratory for testing. Laboratory tests were selected to aid in material classification and provide engineering and index properties useful to our study. Laboratory testing was conducted in general accordance with ASTM procedures and consisted of 66 moisture content determinations (ASTM D 2216), 32 grain-size analyses (ASTM D 422/D 1140), 12 Atterberg limit determinations (ASTM D 4318), and 3 organic analyses (ASTM D 2974). Unit weights of ten frozen samples were determined using a Shannon & Wilson test method.

Laboratory test results are summarized in Tables B1 through B6 in Appendix B, and grain-size distributions are plotted in Figures B1 through B17 in Appendix B. Moisture content data and a summary of the grain size analyses are shown on the boring logs.

3.0 GEOLOGIC SETTING

3.1 Geologic Setting

Kivalina and the surrounding relocation sites lie within the southern section of the Arctic Foothills physiographic province (Wahrhaftig, 1965) near the mouth of the Wulik and Kivalina Rivers. The southern section of the Arctic Foothills is characterized by irregular buttes, knobs, mesas, east-west trending ridges, and intervening gently rolling tundra plains.

The existing townsite is on a barrier island between the Chukchi Sea and the Kivalina Lagoon at the mouth of the Wulik River. The Wulik and Kivalina rivers converge near Kivalina to form a broad lowland plain with low lying mesas and terraces, and rounded mounds of closed system pingos. The lowland is generally poorly drained, and thaw lakes and oxbow lakes representing the former position of the Kivalina and Wulik rivers are common. The lowland is referred to the Kivalina-Wulik Lowland in this report.

Bedrock outcrops at higher elevation in the hills and low mountains surround the lowlands. Bedrock also outcrops in the northern bank of the Kivalina River, marking the northern edge of the lowlands. Bedrock in the area consists of a diverse variety of Devonian to Cretaceous age sedimentary rocks and mafic intrusions, all tightly folded and thrust to the north.

During the Pleistocene the upper valleys of the Kivalina and Wulik Rivers were repeatedly glaciated, likely covering the Kivalina-Wulik Lowland with glacial outwash and fine-grained windblown deposits. Subsequent erosion by rivers has cut down through these deposits forming terraces along the Kivalina River, and mesas like the one that comprises the Simiq site. Based on geomorphic evidence, the upper valley of the Wulik River was last glaciated during the Illinoian stage (Pewe, 1975). Up to 10 miles of marine deposits that parallel the modern day shoreline and extend inland in the lowland areas reflect interglacial marine transgressions.

Kivalina is in an area that is considered to be underlain by thick continuous permafrost (Ferrians, 1965). Permafrost is defined as ground that has had a temperature below 32ºF for two or more years. R&M recorded permafrost temperatures as cold as 24ºF at a depth of 25 feet in their study in 2000. The total depth of permafrost in the Kivalina area is not known. Known permafrost depths are 238 feet at a location around Kotzebue and 1,200 feet near Cape Thompson (Ferrians, 1965).

The thickness of the active layer (the near-surface ground that undergoes an annual freeze-thaw cycle) is largely dependent upon soil type, ground cover, and snow depth. Probing of the active layer during our August 24, 2004, reconnaissance visits to Simiq, Imnakuk Bluff, and Tatchim Isua showed thaw depths ranging from 1.5 to 3.4 feet. The deepest thaw occurred in localized areas with thin or no vegetative cover, such as frost circles.

3.2 General Seismicity

The seismic record in western and northwestern Alaska is typically widespread and diffuse with localized clusters rather than prominent linear trends (Page and others, 1991). Four earthquakes of magnitude 6 or greater have occurred in western Alaska, and four in the Chukchi Sea, all at considerable distances from the Kivalina area. The largest earthquake recorded in the region was magnitude 7.3, followed by two magnitude 6.0 aftershocks that occurred in 1958 approximately 210 miles southeast of Kivalina, near Huslia. Extensive failures in surficial unconsolidated soils within an elongated northeast zone reportedly occurred during this earthquake. The Kaltag Fault System passes south of Huslia, but little significant seismicity has been associated with this fault.

Another magnitude 6.0 earthquake occurred on the Seward Peninsula in 1950, but little is known about this earthquake.

A magnitude 6.9 earthquake occurred in the western Chukchi Sea in 1928 followed by three magnitude 6.0 aftershocks. These earthquakes occurred approximately 155 miles west of Kivalina but are poorly located.

A series of moderate earthquakes triggered by a magnitude 4.6 event occurred approximately 225 miles east of Kotzebue near the east-west trending Kobuk Fault. This fault displaces Quaternary deposits.

Earthquake-induced geologic hazards that may affect the site include landsliding, fault rupture, settlement, and liquefaction and associated effects (loss of shear strength, bearing capacity failures, loss of lateral support, ground oscillation, lateral spreading, etc.). Liquefaction occurs when excess pore pressures develop during undrained cyclic loading of cohesionless soils, causing a reduction in effective stress and strength. The presence of generally continuous permafrost precludes a liquefaction hazard at undeveloped sites, except within the thaw bulbs of rivers and lakes. We note that ground thawing from site development could result in a liquefaction and slope stability hazard, depending on the ground motions implied by current codes.

A geologic map of the area prepared by the Geological Society of America (Neotectonic Map of Alaska, Plafker, Gilpin, and Lahr 1993) was reviewed and does not show faults or linements with evidence of Holocene (0 to 11,000 years) or Quaternary (11,000 to 500,000 years) displacement within approximately 140 miles of the site. The probability of fault rupture in the area is therefore low.

Fault rupture on the seafloor can produce tsunamis, a hazard in coastal areas. There were no reported tsunamis associated with the 1928 earthquakes in the Chukchi Sea. The nearest recorded submarine earthquake that produced a tsunami was a magnitude 6.1 event that occurred in 1991 in the Bearing Sea southwest of St. Mathew Island (West Coast & Alaska Tsunami Warning databases). This earthquake, near the edge of the continental shelf, reportedly produced a small tsunami.

4.0 SITE CONDITIONS

4.1 Simiq

4.1.1 Surface Conditions

The Simiq site consists of an 81-foot-high, roughly 300-acre, flat-topped hill (mesa) in the Lowlands between the Kivalina and Wulik Rivers, approximately 4 miles northeast of the existing townsite (Figure 1). The hill has scalloped edges that appear to have been eroded by the Wulik and Kivalina Rivers (Figure 2). Sanders (2002) postulated the hill may be an erosional remnant of a Pleistocene outwash terrace and could be underlain by gravel. An outwash terrace on the north bank of the Kivalina River appears to be composed of potentially good quality, nonfrost-susceptible gravel.

The top of the mesa has a faint to well-developed, low-center, ice-wedge polygons. The centers of the polygons are typically covered with tussocks, and the lower centers (perimeter) are typically grass covered. The side slopes of the mesa are typically hummocky and covered with dense alder. A small thaw lake occurs on the top of the mesa in the northwest portion of the site. Photographs of the surface are in Appendix C.

Based on our 2004 reconnaissance observations, the top of the mesa appears to be mantled by a layer of silt of unknown thickness, and the sideslopes appear to be covered with a colluvial layer of silt. We probed the soils with a steel rod and hand-dug a series of shallow test pits in the northwest portion of the site during the visit. Frozen ground was encountered at depths ranging from 1.5 to 3.4 feet. The thawed soils overlying the frozen ground consisted of silts and organic silts. There were no exposures of soil or bedrock either on top or on the sideslopes of the mesa, except for a small exposure of organics and silt in the bank of the thaw lake on top of the mesa.

4.1.2 Subsurface Conditions

Two borings were drilled at the site as part of this investigation to explore deeper subsurface conditions at the site. Boring 05-1 was drilled a depth of 20 feet in a low-center, ice-wedge polygon and, aside from a thin surface layer of soil 1.5 feet thick, encountered massive ice throughout the depths explored. Consequently, a second boring (05-2) was drilled in the polygon interior to explore the potential variability in conditions across the polygon.

In Boring 05-2, ice containing silt inclusions was encountered below a soil cover from depths of 2.2 to 13 feet. From depths of 13 feet to the bottom of the boring (20 feet), gray silt and brown organic silt were encountered. These soils contained between 20 and 40 percent visible ice in the form of lenses, veins, and inclusions.

Frozen ground was encountered below the surficial organics at depths of 0.8 and 0.5 foot in borings 05-1 and 05-2, respectively. Groundwater perched on top of the frozen ground was not encountered. We anticipate that after periods of precipitation and during breakup the active layer soils in the low-center polygons may be saturated.

4.2 Imnakuk Bluff

4.2.1 Surface Conditions

The Imnakuk Bluff site is on a bluff on the north side of the Kivalina River, about 3 miles upstream from Kivalina Lagoon and 6 miles north of the existing townsite (Figure 1). The site topography consists of a gentle, southerly slope dissected by two small drainages (Figure 3). Limestone bedrock is exposed in the bluff. A 1998 report by the USACE-AD describes the site being underlain by bedrock beneath a thin veneer of clay-rich permafrost. The geology of the site is described by Golder (1997) as consisting of several feet of clayey marine deposits mantling limestone bedrock. Test pits dug by the Corp in August 1997 indicated that the soils are frozen below a depth of about 3 feet. Outwash gravels are exposed in the bank of the Kivalina River at the upstream end of the site. Sanders (2002) suggested that these deposits may be a source of nonfrost-susceptible granular material for the relocation project.

During our 2004 reconnaissance visit, we observed an exposure of weathered limestone in the bluff next to a tributary creek in the center of the site that appeared to have about 5 feet of colluvial cover consisting of a mix of limestone fragments and silt. Along the top of the bluff we observed a zone of limestone fragments at the surface faintly sorted by frost action. This zone was well-drained and extended about 250 feet uphill from the edge of the bluff. Shallow digging encountered a mix of clayey silt and limestone fragments over frozen ground.

Uphill of the bluff, the drainage deteriorated and the surface was covered with tussocks; low-center polygons were present, suggesting the possible presence of ice wedges. Digging in this area encountered clayey silt with no rock fragments underlying the tundra. Our observations indicated that the soils overlying bedrock might thicken and become ice-rich uphill of the bluff.

Aside from the small drainages, the majority of the site uphill of a narrow zone along the bluff is covered with well-developed low-center, ice-wedge polygons. The polygon interiors are typically covered with tussocks, and the lower centers (perimeter) are typically grass covered. Within the two drainages, patterned ground is typically absent, and the ground surface is grass covered. Photographs of the surface at each boring location an be found in Appendix C.

4.2.2 Subsurface Conditions

For this project, subsurface conditions above the bluff were explored with a series of three borings (05-4, 05-5, and 05-6), and the outwash gravels exposed in the riverbank at the upstream of the site with one boring (05-3). A test pit (TP-05-1) was also dug in the riverbank near 05-3 to obtain a larger, more representative sample of the exposed outwash gravels.

Boring 05-4 was drilled approximately 900 feet uphill of the buff, and borings 05-5 and 05-6 were drilled about 2,500 feet uphill of the bluff (Figure 3). All three borings were drilled in the interior of ice-wedge polygons. Boring 05-6 was located at the margin of the patterned ground in a broad drainage swale. Boring 05-4 was located on the center of a small, nonsorted frost circle where mineral soil was exposed at the ground surface.

Shallow massive ice and ice-rich silt were encountered beneath the surface organics (where they occurred) in all three borings. In Boring 05-5, the massive ice and ice-rich silt extended to the depth of the boring (26 feet). In borings 05-4 and 05-6, these soils were underlain by silts with less visible ice (3 to 5 percent) below depths of 18.5 and 15 feet, respectively. Below 22.5 and 23 feet to the depths explored by 05-4 and 05-6, respectively, a silty sand and sand with silt and gravel were encountered that appeared to be water-sorted. These materials appeared to be either an alluvial or a marine deposit.

Frozen ground was encountered below depths of 0.3 to 2.7 feet, with the depth a function of surface cover. The deepest thaw was observed in Boring 05-4, where mineral soil was exposed at the ground surface. Groundwater perched on top of the frozen ground was not observed; however, we anticipate that after periods of precipitation or during breakup the surficial soils in the low-center polygons may be saturated.

Boring 05-3 was drilled approximately 100 feet uphill from the edge of the riverbank (i.e. terrace) in which outwash gravels were exposed at the upstream end of the Imnakuk Bluff site. The ground surface at the borings was covered with tussocks but was free of patterned ground.

Silt and ice-rich silt containing up to 40 percent visible ice were encountered overlying relatively silty gravel between depths of 7.3 to 10 feet, containing an estimated 20 percent of visible ice. Below 10 feet, relatively clean gravel was encountered that extended to a bedrock contact at a depth of 23 feet. The gravel contained around 5 percent fines.

Test Pit TP-05-1 was hand dug to a depth of 4 feet near Boring 05-3, at the edge of the terrace where the outwash gravels were exposed in a 30-foot-high bank. The purpose of digging TP-05-1 was to collect a larger, more representative sample of the gravels than could be obtained by driving split-spoon samplers into the frozen gravels encountered in the boring, and to investigate the thickness of the silty soils covering the gravels.

In the test pit, about 1 foot of silt with scattered sand and gravel was encountered overlying a silty and sandy gravel to a depth of 2 feet. Below 2 feet, a clean sandy gravel was encountered to the bottom of the test pit (4 feet). The particles in the gravel below 2 feet appeared to be subangular to rounded and relatively hard and durable, with a maximum particle size of 3 inches. The particles are composed predominately of sedimentary rock including carbonates, mudstones, and very fine-grained clastic rocks.

A 10,000-gram sample of clean gravel from a depth of 3.5 to 4.0 feet was collected for gradation analysis. The test results in Appendix B (Figure B17) show the amount finer than 0.02 mm in the sample was 4.3 percent, which classifies the material as S1 (low to medium frost susceptibility) according to the USACE-AD frost classification system.

The gravels exposed in the bank were traced about 3,300 feet upstream from their contact with the limestone at the upstream end of the Imnakuk Bluff site (Figure 3). The bank diminishes to less than 15 feet in height at the upstream end of the gravel exposure, and limestone bedrock becomes exposed at the toe of the bank near the waterline. At the upstream end of our observation the thickness of exposed gravel was estimated to be about 10 feet.

4.3 Tatchim Isua

4.3.1 Surface Conditions

The Tatchim Isua site is on a hill slope between an elevation of 25 and 125 feet at the northern end of Kivalina Lagoon, about 10 miles northwest of the existing townsite. The distinctive feature of this site is a bench, covered with angular, gravel-sized limestone fragments perpendicular to the slope and roughly parallel to the Chukchi Sea coast. Sanders (2002) referred to it as a limestone ridge with a colluvial slope below the ridge. The bench has a relatively flat top with a width of about 450 feet. Both the top of the bench and the bench slope are well drained and sparsely vegetated. The gravel-covered surface of the bench transitions to a relatively flat, tussock-covered slope in the uphill direction, and a tundra-covered slope that transitions to a second, lower bench covered with tussocks in the downhill direction. Small drainages occur along the northwest and southeast edges of the site (Figure 4).

Broad areas of patterned ground consisting of unsorted circles occur across the site above the upper bench. On the slope into the drainage along the northwest edge of the site, the circles become elongated into stripes. Ice-wedge polygon development at the site is limited, with faint polygons observed near the upper limit of the site between borings 05-8 and 05-12.

It was our initial opinion, based on our 2004 reconnaissance visit, that the angular limestone rubble covering the upper bench is indicative of shallow bedrock. We suspected that the slope uphill of the bench may be covered with a layer of silty colluvium that thickens uphill.

To explore subsurface conditions at the site we began by drilling an initial line of four borings across the site, roughly perpendicular to the benches and slope, on approximate 900-foot spacing. One boring (05-10) was located on the lower bench, and three (05-7, 05-8, and 05-9) were drilled on or above the upper bench (Figure 4). At the request of USACE-AD we drilled four additional borings 1,000 to 1,200 feet left and right of the initial line as shown in Figure 4. The offset from the initial line of borings was slightly less than requested due to the presence of drainages at greater distances.

4.3.2 Subsurface Conditions

The borings were advanced to depths ranging from 8.3 to 21 feet, with the depths commonly limited by bedrock. On the lower bench, ice-rich silt was encountered to the bottom of the boring (20.2 feet), with a layer of massive ice between depths of 10 and 15.3 feet.

Relatively shallow bedrock was encountered on and above the upper bench at depths ranging from 4.5 to 11.5 feet. Bedrock appears to be deeper at the uphill end of the site and toward the drainages on the sides of the site, although a definite trend in the depth to bedrock is not clear. The bedrock encountered in the borings was typically weathered and narrowly jointed. In Boring 05-1 the bedrock appeared to be a limestone that reacted strongly with HCL. Bedrock in the remaining borings consisted of a siltstone and claystone that did not react with HCL, except in 05-8 where weak reaction was observed. We note that the contact between soil and bedrock was sometimes indistinct (as in 05-7), as the bedrock is typically highly weathered and both the soils and bedrock are modified by frost action (cryoturbation) and solifluction processes.

The bedrock was overlain by silty gravel in Boring 05-7, which was drilled on the gravel-covered surface of the upper bench. Beneath the tussock-covered surface uphill of the bench, silty soils containing sand and gravel and gravelly soils were encountered overlying bedrock. These soils appear to be colluvium and residual soils modified by frost action. In Borings 05-13, thin peat layers were encountered at 3.1 and 4 feet, possibly representing former surficial organics buried by solifluction processes.

Except in Boring 05-7, the soils overlying bedrock were typically frozen at shallow depths (0.7 to 2.5 feet) and ice rich, with 15 to 50 percent visible ice (by volume) common. Massive ice and ice with soil inclusions were encountered from 1 to 3.1 feet in 05-11, 7.2 to 11.5 feet in 05-13, 3.2 to 4.3 feet in 05-14. The soils in Boring 05-13 appeared to contain the most ice. The soils covering bedrock in 05-7 were frozen below a depth of 6.5 feet and had the least amount of visible ice (an estimated 5 percent).

The weathered bedrock underlying the soil cover contained up to 15 percent visible ice as inclusions and joint fillings. The ice content typically decreased to less than 5 percent within the depths explored. In Boring 05-13 the bottom sample from 14.5 to 15 feet contained an estimated 5 to 15 percent visible ice.

Moisture contents in the bedrock, in the initial line of borings through the center of the site, ranged from 4 to 7 percent. In the offset borings along the northwest and southeast edge of the site higher moisture contents in the bedrock, ranging from 6 to 39 percent, coincided with higher ice contents. The moisture contents were typically higher near the top of the bedrock and appeared to decrease with depth. The highest moisture contents were observed in Boring 05-13.

Groundwater perched on top of the frozen ground was not encountered at the site. We anticipate that after periods of precipitation or during breakup, the active layer soils at the site may be partially saturated.

5.0 THERMAL ANALYSES

The permafrost at the potential relocation sites, particularly at Simiq and Imnakuk Bluff is highly thaw unstable; therefore, thaw protection of the permafrost at these sites will be an important aspect of the project. Preliminary calculations by R&M in 2000 indicated that a gravel pad thicknesses of 11.5 to 14.8 feet would "reduce the depth of thaw penetration into the ice-rich soils to nearly zero." Their calculations were performed using the Alaska Department of Transportation & Public Facilities (ADOT&PF) BERG2 computer program. The program uses methodology similar to the Modified Berggren method to estimate thaw and freeze depths in layered soil systems. The design thawing index or degree Fahrenheit days (°F-days) above freezing (also referred to as freezing degree days or FDD in this report) for Kivalina given in their report is about 2,750. The source of this information appears to be the Environmental Atlas of Alaska by Hartman and Johnson (1984). The design thawing index, which is the average thawing index for the three warmest summers of a 30-year record appears to be based on pre-1976 data. Notable warming has occurred in the air temperature records of numerous recording stations in Alaska since 1977. Given the dated nature of the temperature record used to estimate thaw depths and the noted warming, we revisited the analysis to include more recent data. In addition, the design thawing index used in the initial analyses may have been interpreted incorrectly from Plate 25B of the environmental atlas. A copy of Plate 25B from the atlas is shown in Appendix F.

Using the ADOT&PF BERG2 computer program, we made a preliminary estimate of the thickness of both an insulated and uninsulated gravel pad that would be required to prevent the seasonal thaw front from advancing into the subgrade soils. We considered the design-thawing index to be the average thawing index for the three warmest summers of the last 30 years of available air temperature records.

The Alaska Climate Research Center was our source of air temperature information (daily maximum and minimum temperatures) for recording stations in Kotzebue (1949 to 2002) and Kivalina (1973 to 1975). The record for Kivalina is too short to be useful for design purposes, so our analyses are based on the Kotzebue record.

From the Kotzebue record, thawing indices were calculated for each year from the daily temperatures. The years with highest indices for the period of record are summarized below, and indices for the entire record are plotted in Figure 5.

HIGHEST THAWING INDICES FOR KOTZEBUE
(1949-2002)

Year	Thawing Index °F-days
1957	2,336
1958	2,306
1972	2,317
1977	2,484
1978	2,653
1979	2,371
1990	2,539
1991	2,395
1995	2,381
1997	2,504

The ten highest thawing indices range from 2,306 to 2,653 °F-days. The average of the highest three values in the most recent 30-year period of the record is 2,565 °F-days. A notable increase in the mean thawing index is observed around 1997. The pre-1977 mean is 1,974 °F-days; whereas, the post 1977 mean is 2,172 °F-days. The mean for the entire record is 2069 °F-days.

A warming trend is being observed in the Arctic, although the rate and magnitude of warming that will occur is uncertain. A linear regression through the entire Kotzebue record indicates the rate of increase in the thawing index is about five °F-days per year, although the correlation coefficient for this relationship is poor (r = 0.31).

We used the average of the highest three, thawing index values in the record (2,565 °F-days) to estimate the thickness of gravel fill that would be required to prevent the subgrade from thawing. The Alaska Environmental Atlas (1984) indicates a design-thawing index of 2,400 °F-days for Kotzebue. We note that NOAA-National Weather Service data (Figure 6) shows that the thawing index for Kotzebue in 2004 was 140 percent of normal, and the projected index for 2005 is 120 to 125 percent of normal. The normal index is considered to be 2,000 °F-days. We have therefore also included calculations for indices of 2,400; 2,700; and 2,800 °F-days.

In the analysis we assumed a gravel pad containing 4 percent moisture and insulation buried 2 feet below grade. We used presumptive thermal properties in the program, which are based on Kersten (1949). The material properties are summarized below.

SUMMARY OF MATERIAL PROPERTIES

Material	Dry Unit Weight (lb/ft^3)	Moisture Content (%)	Thawed Thermal Conductivity (Btu/h-ft-°F)	Frozen Thermal Conductivity (Btu/h-ft-°F)	Thawed Heat Capacity (Btu/ft°-°F)	Frozen Heat Capacity (Btu/ft°-°F)
Gravel Fill	130	4	1.37	1.15	27.3	24.7
Insulation	1.8	0	0.02	0.02	3.0	3.0

The ground surface, thawing index used in the calculation was related to the air thawing index using and n-factor value for thawing. Reported n-factor values in the literature vary. Table 3-5 in *Frozen Ground Engineering* by Andersland and Ladanyi (2004) suggests that a thawing n-factor for a gravel surface might range from 1.3 to 2.0. Based on this information and our experience, we selected an n-factor of 1.6 in the calculations.

The results of the calculations are summarized in the Table below and plotted in Figure 7.

ESTIMATED DEPTH OF THAW (FEET)

Insulation Thickness (inches)	Air Thawing Index °F-days			
	2,400	2,565	2,700	2,800
0	14.0	14.5	14.8	15.0
1	9.5	9.9	10.2	10.4
2	7.0	7.3	7.5	7.7

Insulation Thickness (inches)	Air Thawing Index °F-days			
	2,400	**2,565**	**2,700**	**2,800**
4	4.8	5.0	5.1	5.2
6	4.0	4.1	4.2	4.3
8	3.7	3.7	3.8	3.9
10	3.5	3.6	3.7	3.7
12	3.5	3.6	3.6	3.7

Without insulation, the preliminary analyses suggest that 14 to 15 feet of gravel might be required to contain the seasonal thaw for the design thawing index. This is a similar to the estimate in the previous study, although the estimates are based on a different set of temperature records and assumptions. The calculations show that a few inches of insulation significantly reduces the thaw depth with diminishing benefit as the insulation thickness increases.

The above calculations assume that the surface of the fill is exposed to ambient outside air temperatures and do not consider the effect of buried utilities or at-grade heated structures.

Polystyrene insulation used in ground insulation applications will degrade in the presence of hydrocarbon-based fuel or fuel vapors. We know of several instances where insulation placed beneath structures has been lost due to fuel spills, compromising the frost protection system and resulting in settlement. We therefore recommend using insulation with caution. If insulation is used, it is imperative to protect it from fuels, solvents, and fuel and solvent vapor degradation.

6.0 CONCLUSIONS

6.1 Simiq

Our exploratory drilling at Simiq indicates the site is underlain by shallow, highly thaw-unstable permafrost. Over 20 feet of massive ice were encountered in a boring drilled in an ice-wedge polygon, and 13 feet of ice with silt inclusions overlying ice-rich silt were encountered in a boring drilled in the center of a polygon. Outwash gravels, as speculated, were not encountered within the depths explored.

We anticipate that site development will result in warmer ground surface temperatures, partial thawing of the underlying permafrost, and an increase in the thickness of the active layer. As the permafrost thaws, we anticipate settlement damaging to structures, utilities, and infrastructure will occur. Therefore, either the permafrost will have to be protected from thawing, facilities will have to be designed to tolerate settlement, or deep foundations might have to be used to support structures, with structures elevated to thermally decouple them from the ground.

Options to prevent thawing and maintain the integrity of the permafrost include construction of an earthen pad that contains the seasonal thaw, a combination of an earthen fill and insulation, or passive or active refrigeration. Preliminary calculations indicate that 14 to 15 feet of gravel fill might be required to protect permafrost underlying road and runway embankments from thawing.

Based on the results of our site characterization, we have the following conclusions and comments regarding development of this site.

1. Our explorations indicate the site is underlain by highly thaw-unstable permafrost that will partially thaw in response to development, resulting in potentially damaging settlements.

2. The problems and risks associated with developing a site underlain by highly thaw-unstable permafrost make the site undesirable from a geotechnical standpoint. Even properly designed facilities are at risk, given uncertainties in our understanding of future climate trends.

3. Conceptually, commercial, municipal, or public structures might be elevated on pile foundation systems that may or may not be passively refrigerated. Residential structures could be elevated on nonrefrigerated piles or a post-and-pad foundation system that are founded in a fill sufficiently thick to prevent thawing of the underlying permafrost. Fuel and water tanks could also be founded on a pile foundation system. Refrigerated shallow foundation systems could be considered for structures with heavy floor loads, such as equipment and maintenance shops or tank structures. Performance is expected to be better and the risk of excessive settlement or failure is generally less using passively-refrigerated pile foundations systems to support structures rather than post-and-pad or refrigerated, shallow foundation systems. Creep settlement in ice-rich soils might limit the design of foundation systems at the site and should be considered.

4. Pile foundations would develop capacity in the soils underlying the massive ice at the site, and therefore have to be significantly deeper than the explorations conducted for this project. In Boring 05-1 there were no suitable soils encountered within the depth explored (22.5 feet) that could be used to develop pile capacity.

5. Embankments for roadways and runways will need to be sufficiently thick to prevent thawing of the underlying permafrost. Insulation could be used to reduce embankment thickness and maintain the integrity of the permafrost. Thinner embankments might be possible if some settlement and periodic filling of thaw settlement depressions and maintenance of the embankment are acceptable until an equilibrium thickness of fill material is reached.

6. Grade beneath elevated structures and adjacent roadways should be similar to prevent ponding of water beneath structures. Site fills should be graded to prevent ponding of water in the townsite.

7. Due to the potential for large differential settlement, aboveground water and sewer utilities in either an aboveground utilidor or individual insulated lines are more appropriate for the site than buried lines or utilidors. Buried utilities might be feasible if they are buried in an insulating fill designed to minimize the thermal impact to the permafrost. Aboveground construction would thermally decouple the utilities from the subgrade and allow grade adjustments if necessary. When a water or sewer line freezes, aboveground utilities would be easier to repair. Direct burial of settlement-sensitive gravity, pressure, or vacuum sewer systems might be risky due to the potential for settlement.

8. Insulation could be used to reduce gravel fill requirements. Higher-moisture-content, finer-grained soils could also be used to reduce thaw penetration and fill thicknesses. Finer-grained fills would be frost susceptible and would be better suited for areas that could tolerate seasonal ground movements due to frost action.

9. Construction of sewage lagoons for wastewater treatment is a concern. Although high lagoon dikes could be designed to account for settlement, they may experience sudden failure if an underlying massive ice lens or wedge thaws, resulting in settlement and causing a membrane liner to rupture. In an unlined lagoon, a piping type of failure is likely to occur along lenses or wedges of massive ice. A sewage lagoon constructed with earthen dikes should be sited in an area without massive ice and the possibility of large differential settlement. Treatment in a natural pond or lake would avoid some of stated concerns with a constructed lagoon and could be a better alternative. Septic tanks and a package treatment plant would also avoid some of the potential problems with a constructed lagoon.

10. From a geotechnical standpoint, due to potential severe thaw instability problems, we do not recommend Simiq as a new townsite.

6.2 Imnakuk Bluff

6.2.1 Site Development

Our exploratory drilling indicates the Imnakuk Bluff site is also underlain by highly thaw-unstable permafrost. Massive ice and ice-rich silt permafrost were encountered in all three borings completed at the site. In one boring the massive ice and ice-rich silt extended to the depth explored of 26 feet. In the other two borings, lower-ice-content silts (3 to 5 percent ice) were encountered below depths of 15 and 18 feet and were underlain by granular permafrost below about 23 feet. The granular soils in the base of these boring appeared to be water sorted and may be alluvium or a marine deposit. All three borings at this site were drilled in the interior of ice-wedge polygons. We did not drill in the ice wedge portion of the polygons, but expect the ground ice content in the ice wedges will be even higher than those observed in the borings, based on our experience at Simiq.

As at Simiq, we anticipate severe thaw settlement problems if the Imnakuk Bluff is developed, unless the permafrost is protected from thawing, facilities are designed to tolerate settlement, or deep foundations are used to support structures and structures are elevated to thermally decouple them from the ground.

Our conclusions and recommendations developed for Simiq apply to Imnakuk Bluff with the following notes.

1. The granular permafrost encountered in two of the borings might be a suitable bearing stratum for pile foundation systems. Relatively large pile capacities could be developed, and concerns about creep settlement would be reduced.

2. The ice wedge of the polygons at the site were not explored, and the extent of massive ice in the ice wedges is unknown.

3. Our drilling and observations indicate that the Imnakuk Bluff site has a nearby source of granular fill that is likely suitable for development of the site.

4. From a geotechnical standpoint, due to potential for severe thaw instability problems, we do not recommend Imnakuk Bluff as a new townsite.

6.2.2 Material Source

Our observations, drilling, and laboratory testing indicate the outwash gravels exposed in the back along the Kivalina River upstream of the Imnakuk Bluff are relatively clean and durable and, in our opinion, are likely suitable as a source of structural fill for the development of a new townsite. Gradation testing of a sample from Test Pit TP-1 indicates that the material may have a low to medium susceptibility to heaving or weakening due to frost action. In our opinion, additional sampling and laboratory frost-heave testing may show that the material is nonfrost susceptible (NFS).

The boring and test pit indicate that a cap of siltier, frost-susceptible, colluvial material overlies the outwash gravels, and this cap material thickens uphill perpendicular to the riverbank. Our explorations also suggest that the contact of the gravel with the underlying bedrock rises and the thickness the outwash gravels decreases uphill, perpendicular to the riverbank. Furthermore, our observations indicate that the thickness of the gravels exposed in the riverbank decrease in an upstream direction.

Our explorations and observations indicate on the order of 200,000 yards of potentially suitable gravel reserves in the terrace along the Kivalina River upstream of the Imnakuk Bluff site. This assumes the gravel deposit is 100 feet wide with an average thickness of 20 feet at the downstream end, and 100 feet wide with an average thickness of 10 feet at the upstream end. Additional exploration should be completed to confirm these reserves.

6.3 Tatchim Isua

Our exploratory drilling indicates that the upper bench and the area above the upper bench at Tatchim Isua are underlain by relatively shallow, weathered bedrock. The lower bench appears to be underlain by thick, ice-rich, fine-grained permafrost.

The area above the upper bench appears to have a mantle of colluviual soils ranging in thickness from 4.6 to 11.5 feet that are frozen and commonly ice rich and highly thaw unstable. The soil mantle generally appears to be thicker at the uphill end of the site, although there is no definitive trend in the thickness.

The bedrock along the leading edge of the bench is a weathered limestone; however, the majority of the borings at the site encountered a weathered siltstone or claystone. Ice and moisture contents in the bedrock encountered in the initial line of borings through the center of the site were relatively low. Higher moisture and ice contents were encountered in the upper portion of the bedrock in the borings on the northwest and southeast sides of the site near the adjacent drainages. The ice and moisture contents typically appear to decrease with depth in the bedrock.

Based on the results of our investigation, we have the following conclusions and comments regarding development of this site.

1. Our explorations indicate the upper bench is underlain by potentially thaw-stable bedrock with areas of slightly to moderately thaw-unstable, weathered bedrock near the contact with the overlying soils.

2. Thaw instability in the bedrock appears to be greater along the northwest and southeast sides of the site into the adjacent drainages. Thaw instability appears to decrease with depth in these borings.

3. Uphill of the gravel-surfaced bench, bedrock is overlain by a highly thaw-unstable mantle of colluvial soils 4.6 to 11.5 feet thick at the drilled locations.

4. Relocation to Tatchim Isua has the potential to avoid many of the difficulties associated with developing a site underlain by deep, highly thaw-unstable permafrost.

5. Our explorations indicate that the potential for thaw instability along the gravel-surfaced edge of the bench is low. However, the active layer soils are potentially frost susceptible. Embankments for roadways and runways constructed in this area will need to be sufficiently thick to support structural loads. Larger structures could be founded on conventional foundation systems, and residential structures could be founded post-and-pad or conventional foundations bearing on structural fill of limited thickness. Sewer and water utilities could be directly buried in the weathered rock and soil or in a thin pad, and would not be impacted by large differential movements due to permafrost thawing. Lakes at the base of the hill might be considered for wastewater treatment and disposal. On-site wastewater disposal with a leach field would not be appropriate due to shallow bedrock and permafrost. Road and runway sections could be relatively thin, about 2 to 4 feet. Fuel and water tanks could also likely be founded at grade on a limited layer of structural fill. General site preparation for structures might involve replacing the surficial frost-susceptible soil and localized areas of potentially thaw-unstable bedrock with a stable nonfrost-susceptible fill.

6. Uphill of the gravel-covered bench, the highly thaw-unstable nature of the soil that mantles the bedrock must be considered. The highly thaw-unstable soil cover and localized areas of the weathered bedrock could be excavated to mitigate thaw settlement problems in construction of road and runway embankments, utilities, and structures. If

the thaw-unstable cover were excavated, structures could be constructed on conventional foundation systems founded on limited structural replacement fills. Residential structures could be constructed using conventional or post-and-pad foundation systems that bear on a limited layer of structural fill. Fuel and water tanks could also likely be founded at grade on a limited layer of structural fill. Sewer and water utilities could be directly buried in the weathered rock or in a thin pad and would not be impacted by large differential movements due to permafrost thawing.

7. Alternatively, if the thaw-unstable soil cover overlying bedrock is not removed, then methods to prevent the soils from thawing outlined for Simiq and Imnakuk Bluff should be considered in the development of the site. Conceptually, both public facilities and residential structures could be founded on piles bearing in the shallow bedrock underlying the site.

8. We expect that the weathered bedrock at the site will disintegrate to silt and clay where it is exposed in a cut. It will therefore be important to cover any excavations in this material with a durable, granular fill.

9. We expect that the weathered bedrock at the site will be frost susceptible. Unheated foundations should consider the frost susceptible nature of these materials in design. It may be necessary to limit the seasonal freezing of these soils with the use of insulation. Good drainage will be important to reducing frost action in these soils.

10. Utilities and road and runway embankments constructed on the lower bench or adjacent areas underlain by highly thaw-unstable soils should be designed to limit permafrost thawing as described for Simiq and Imnakuk Bluff.

11. Due to the possibility of reducing or eliminating potential thaw instability problems, Tatchim Isua is a relatively good relocation site from a geotechnical standpoint.

7.0 LIMITATIONS

The analyses, conclusions, and discussions contained in this report are based on site conditions as they were encountered in our borings. They further assume that the explorations are representative of the subsurface conditions throughout the site.

Unanticipated soil conditions are commonly encountered and cannot be fully determined by merely taking soil samples or test borings. Such unexpected conditions frequently require that additional expenditures be made to obtain a properly constructed project. Therefore, some contingency fund is recommended to accommodate such potential extra costs.

If substantial time has elapsed between the submission of this report and the start of work at the site, or if conditions have changed because of natural causes or construction operations at or adjacent to the site, we recommend that this report be reviewed to determine the applicability of the conclusions and discussions considering the time lapse or changed conditions.

This report was prepared for the exclusive use of TNH, Inc., to assist in the relocation studies. It is not a warranty of subsurface conditions, such as those interpreted from the boring logs and presented in discussions of subsurface conditions in this report. The scope of our services did not include any environmental assessment or evaluation regarding the presence or absence of wetlands or hazardous or toxic materials in the soil, surface water, groundwater, or air at the site.

Shannon & Wilson, Inc., has prepared the attachment *Important Information About Your Geotechnical/Environmental Report* in Appendix D to assist you and others in understanding the uses and limitations of our reports.

We trust that this information is sufficient for your needs at the present time. If you have any questions, please do not hesitate to call.

Sincerely,

SHANNON & WILSON, INC.

Frank Wuttig
Principal Engineer

Reviewed by

Rohn D. Abbott, P.E.
Senior Vice President

STATE OF ALASKA
49TH
ROHN D. ABBOTT
4227-E
10/12/06
REGISTERED PROFESSIONAL ENGINEER

8.0 REFERENCES

Andersland, O.B. and B. Ladanyi. 2004. *Frozen ground engineering*. American Society of Civil Engineers & John Wiley & Sons. Hoboken, New Jersey.

DOWL Engineers. 1994. *City of Kivalina, Kivalina relocation study, Kivalina, Alaska.*

DOWL/BBFM Joint Venture. 1998. *Geotechnical investigation Kivalina borrow material exploration, Kivalina, Alaska.*

Ferrians, O. 1965. *Permafrost map of Alaska*. U. S. Geological Survey Miscellaneous Investigation Series Map I-445.

Golder Associates. 1997. *Phase 1 geophysical groundwater source investigation, Kivalina, Alaska.*

Kersten, M.S. 1949. *Thermal properties of soils.* University of Minnesota Engineering Experiment Station Bulletin No. 28. St. Paul Minnesota.

Page, R.A., N.N. Biswas, J.C. Lahr, and Hans Pulpan. 1991. Seismicity of continental Alaska, *in* D.B. Slemmons, E.R. Engdahl, M.D. Zoback, and D.D. Blackwell, eds., *Neotectonics of North America*: Boulder, Colorado. Geological Society of American, Decade Map Volume 1. p 47-68.

Pewe, T.L. 1975. *Quaternary geology of Alaska*. U.S. Geological Survey Professional Paper 835. United States Government Printing Office, Washington.

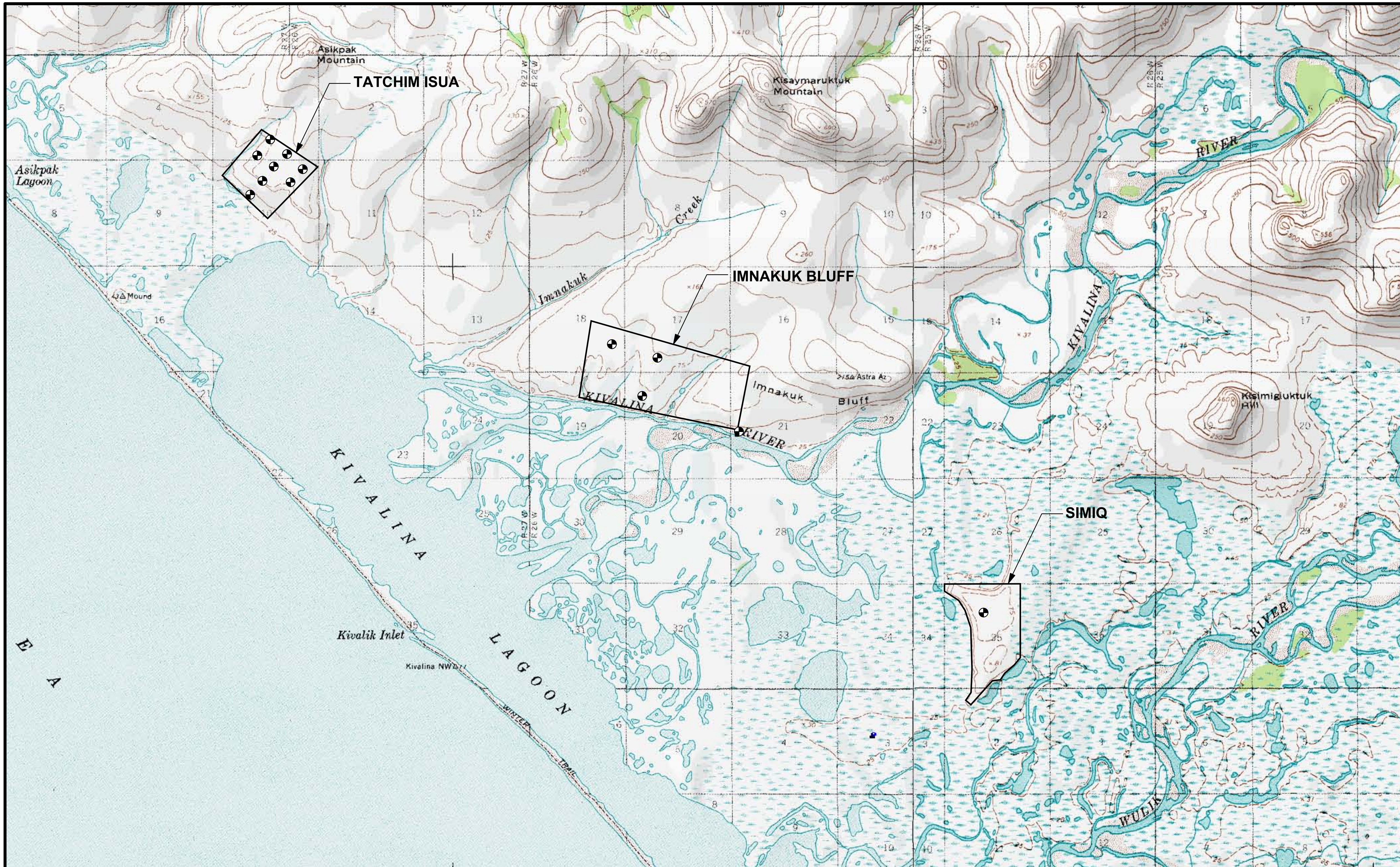
R&M Consultants, Inc. 2000. *Reconnaissance geotechnical investigation Kivalina relocation, Kivalina, Alaska.*

Sanders, R. 1998. *Kivalina gravel requirements, problems and recommendations (Draft)*. U.S. Army Corps of Engineers.

Shannon & Wilson, Inc. 2004. *Geotechnical review and assessment, Kivalina relocation project, Kivalina, Alaska.*

Shannon & Wilson, Inc. 1982. *Geotechnical feasibility study Kivalina Airport Expansion, Kivalina, Alaska.*

Wahrhaftig, C. 1965. *Physiographic divisions of Alaska*. U.S. Geological Survey Professional Paper 482. United States Government Printing Office, Washington.



Explanation:

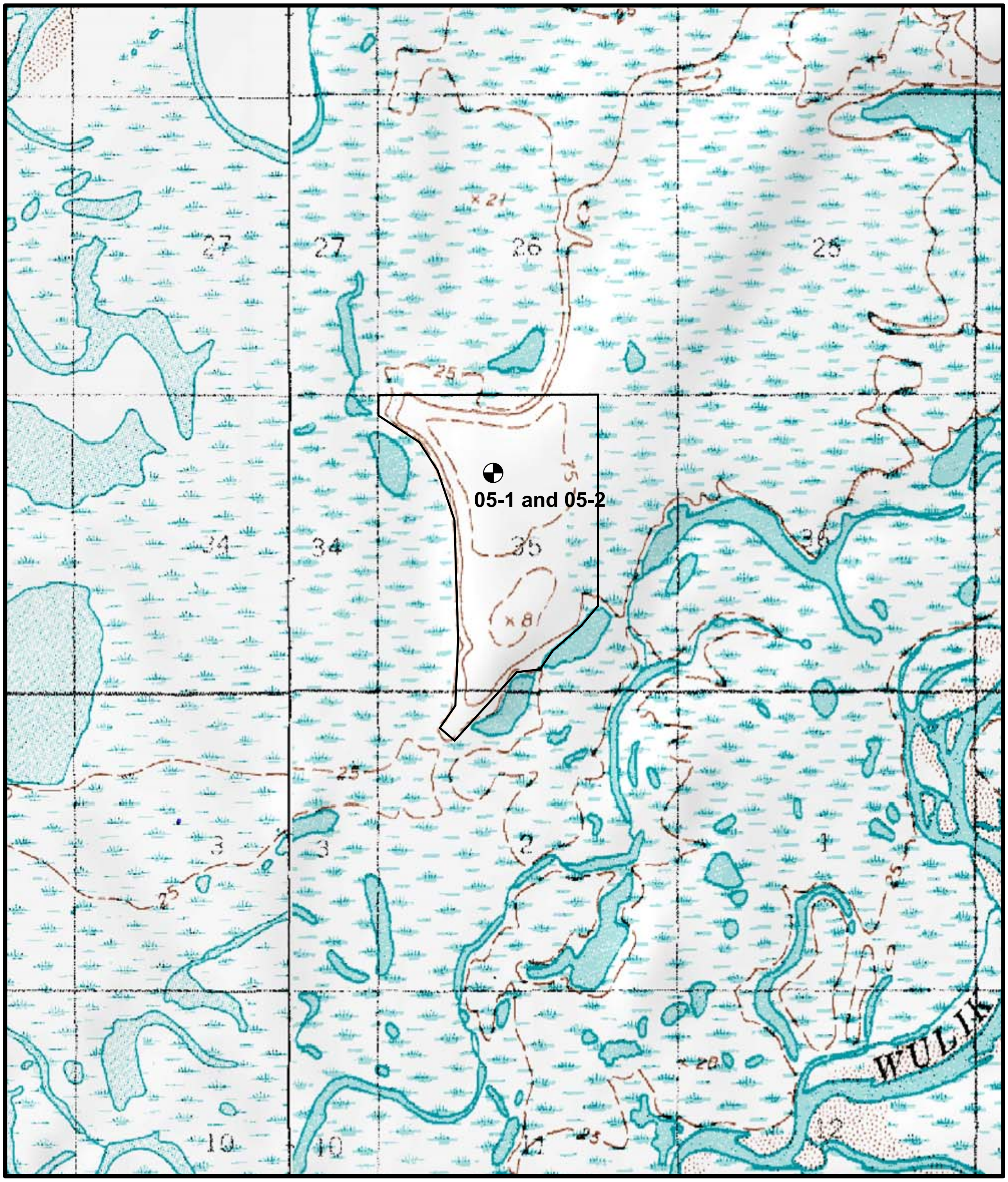
⊕ - boring location

Approximate North

Approximate Scale

0 1/2 1 2 mi

Geotechnical Investigation Potential Relocation Sites Kivalina, Alaska	
POTENTIAL RELOCATION SITES	
2005	31-1-01874-002
SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS	**Figure 1**



Explanation:

- boring location and number

05-1

Approximate North

Approximate Scale

0 1/4 1/2 1 mi

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

SIMIQ SITE

2005 31-1-01874-002

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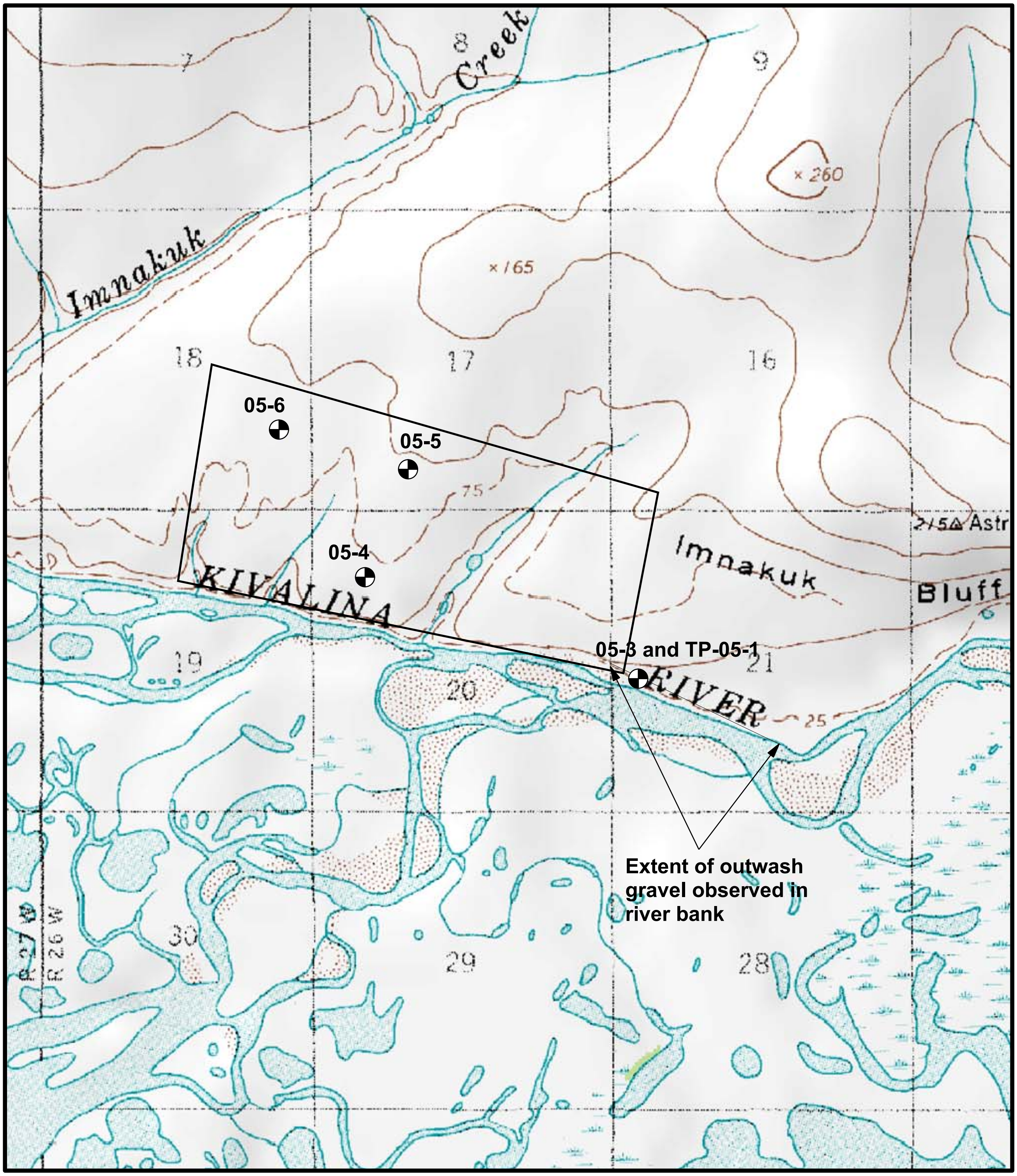
Figure 2



Explanation:

- boring location and number
05-5

Approximate North

Approximate Scale
0 1/4 1/2 1 mi

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

IMNAKUK BLUFF SITE

2005 31-1-01874-002

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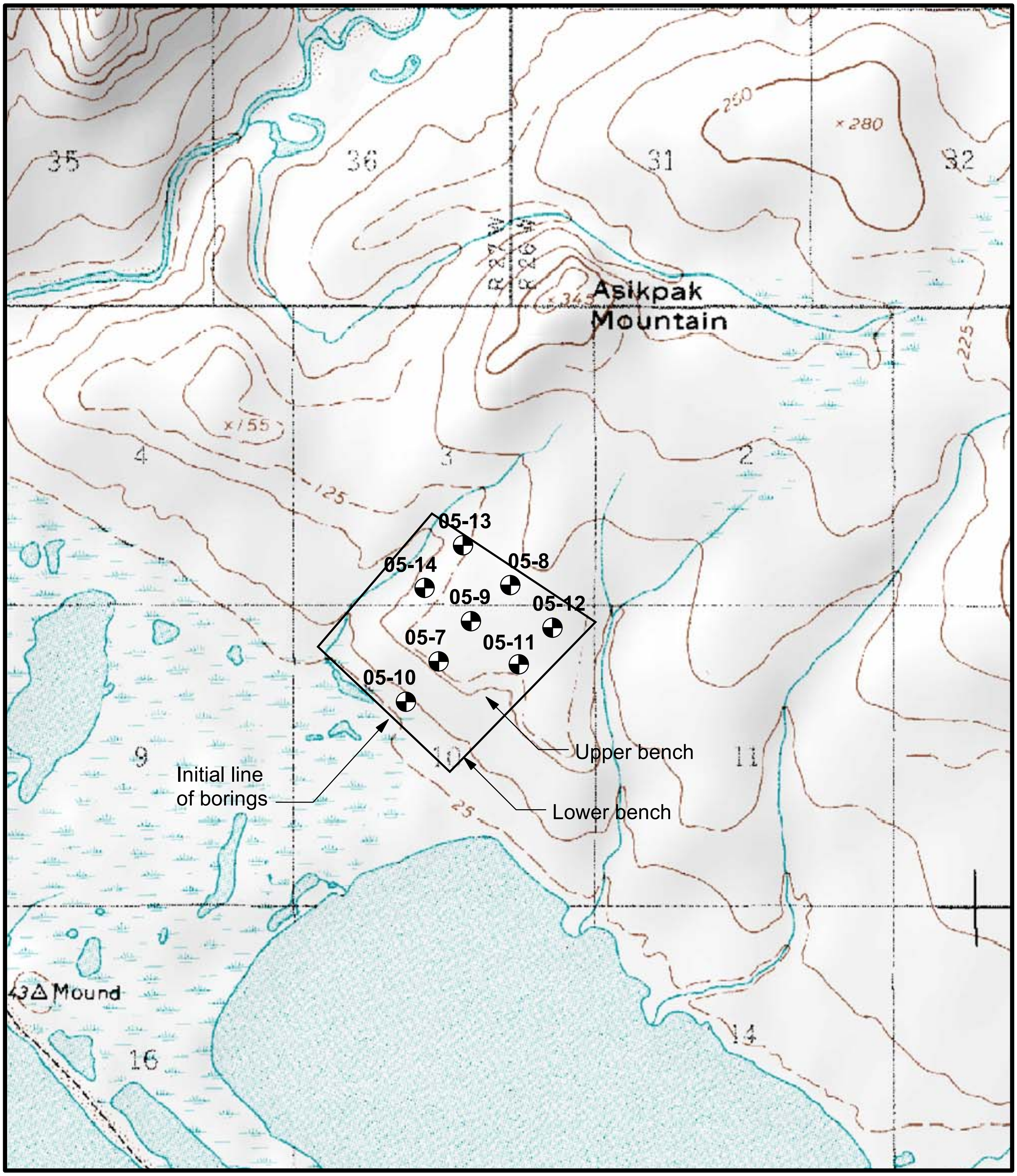
Figure 3



Explanation:

05-8 - boring location and number

Approximate North

Approximate Scale

0 1/4 1/2 1 mi

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

TATCHIM ISUA SITE

2005 31-1-01874-002

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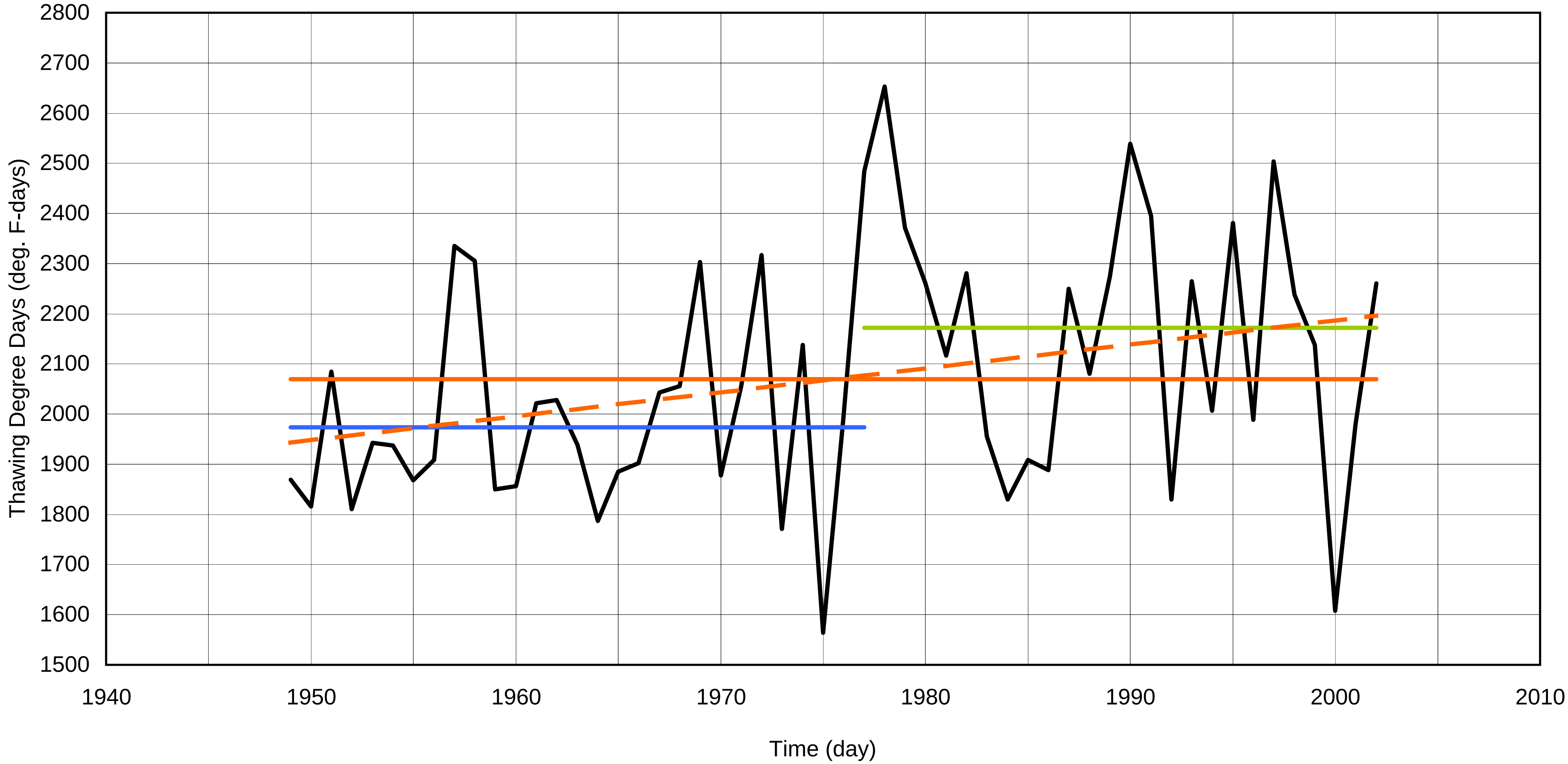
Figure 4



Legend:

- Thawing Degree Days (TDD), 1949-2002
- Mean TDD 1949-1976
- Mean TDD 1977-2002
- Mean TDD 1949-2002
- Linear Regression 1949-2002 (correlation coefficient = 0.31)

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

SUMMARY OF THAWING DEGREE DAYS
KOTZEBUE WSO AIRPORT, ALASKA
1949-2002

2005 31-1-01874-002

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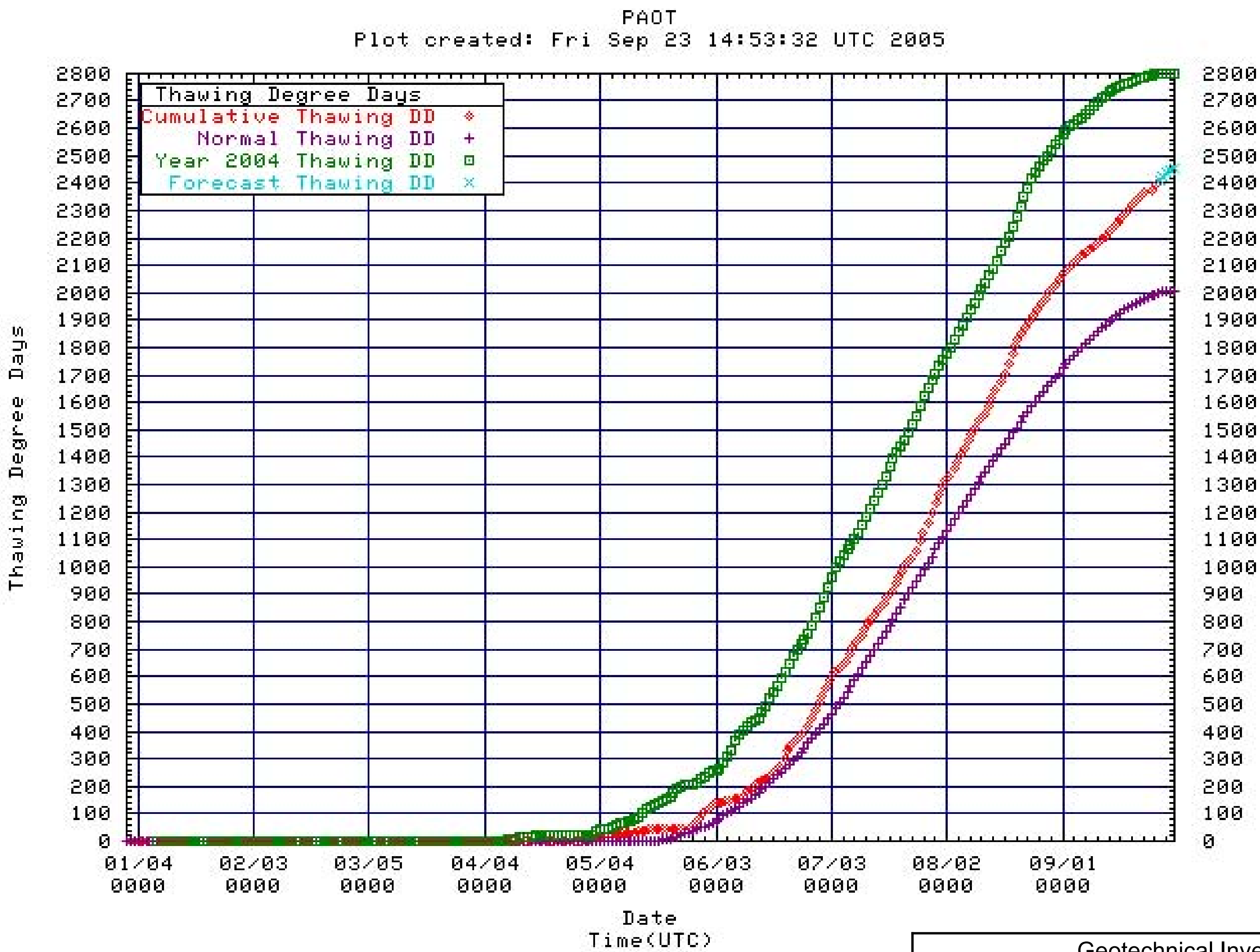
Figure 5



Source of infromation: NOAA National Weather Service (09-23-05)

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

RECENT THAWING DEGREE DAYS

2005

31-1-01874-002

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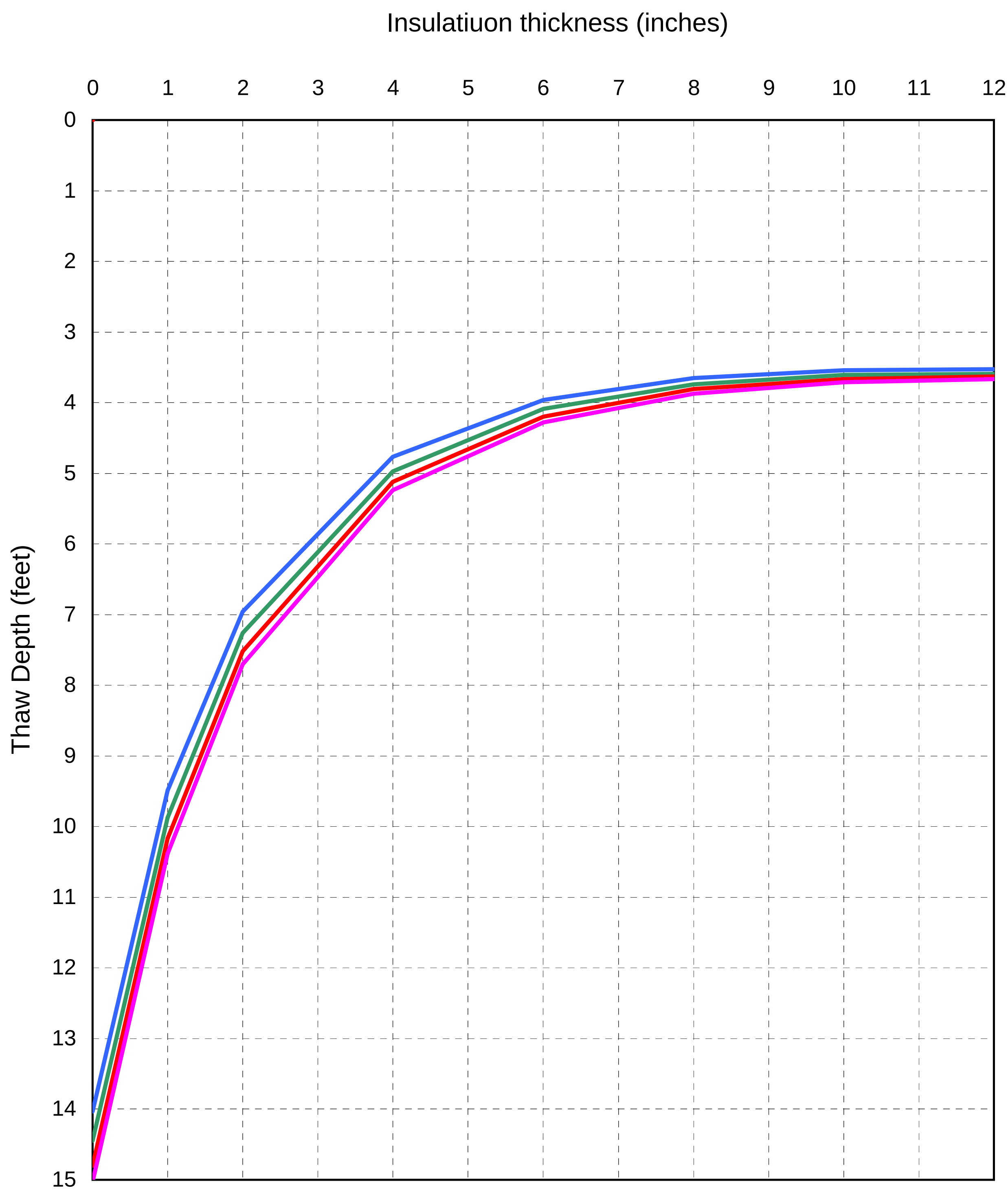
Figure 6



Legend:

- 2400 FDD
- 2565 FDD
- 2700 FDD
- 2800 FDD

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

ESTIMATED THAW DEPTH IN GRAVEL

2005 31-1-01874-002

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Figure 7

APPENDIX A

Boring Logs

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EXPLORATION LOG

Project:	Potential Relocation Sites, Kivalina, Alaska
Project No.:	31-1-01874-002
PAGE	1 OF 1
Date:	28 Jul 2005
Drilling Agency:	☐ Alaska District ☒ Other Discovery Drilling
Elevation Datum:	☐ MSL ☐ other
Location: (NAD27)	Latitude: N67.78609 Longitude: W164.47415
Top of Hole Elevation:	
Hole Number, Field:	05-1
Permanent:	
Operator:	Jordan Wininger
Inspector:	Frank Wuttig
Type of Hole:	☐ other ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer
Depth to Groundwater:	Not encountered
Depth Drilled:	21.0 ft
Total Depth:	22.5 ft
Hammer Weight:	340 lb
Split Spoon I.D:	2.5 in.
Size and Type of Bit	3 1/4" I.D. HSA and 6" SSA
Type of Equipment:	CME 45 with cathead and rope
Type of Samples:	Drive

Depth (ft)	Lithology	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks
														Surface: Grass, low-center polygon perimeter
0				F4		PT	Peat							Organics.
1			Vr Vx	F4		OL	Organic soil							Brown, organic SILT; frozen Nbe, Vr and Vx; 10 to 15% visible ice.
2			ICE				Ice							Massive ICE, generally opaque and white; reticulate cracking pattern; cracks frequently stained brown.
3		S-1												
6		S-2												
7		S-3												
9		S-4												
10		S-5												
11		S-6												
12		S-7												
14		S-8												
14.5		S-9												
15		S-10												
17		S-11												
18		S-12												
20		S-13												
21		S-14												
22.5														Bottom of Boring at 22.5 ft Boring Completed 28 Jul 2005 PID=(Cold/Hot) Photoionization Detector

Depth scale: 0–35 ft

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EXPLORATION LOG

Project: Potential Relocation Sites, Kivalina, Alaska
Project No.: 31-1-01874-002

Date: 28-Jul-2005

Drilling Agency: ☐ Alaska District ☒ Other Discovery Drilling

Elevation Datum: ☐ MSL ☐ other

Location: (NAD27) Latitude: N67.78620 Longitude: W164.47412

Top of Hole Elevation:

Hole Number, Field: 05-2 Permanent:

Operator: Jordan Wininger

Inspector: Frank Wuttig

Type of Hole: ☐ other ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: Not encountered

Depth Drilled: 18.5 ft

Total Depth: 20.0 ft

Hammer Weight:	Split Spoon I.D:	Size and Type of Bit	Type of Equipment:	Type of Samples:
340 lb	2.5 in.	3 1/4" I.D. HSA and 6" SSA	CME 45 with cathead and rope	Drive

Surface: Tussocks, low-center polygon interior

Depth (ft)	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks
0					PT	Peat							Organics.
0.5–2		Vs Vx	F4		ML	Silt							Grayish-brown SILT and brown organic SILT; frozen Vs and Vx up to 5 mm in size; 20 to 40% visible ice.
2–3	S-1	Vs		30 25 40	PT	Peat						162	Brown PEAT; frozen Vs; lenses 1 to 3 mm thick; 10% visible ice.
3–5	S-2	ICE ML		25 33 35		Ice with soil inclusions							ICE with gray silt inclusions; inculsions primarily horizontal.
5–7	S-3	Nbe Vs Vx	F4	35 30 37	ML	Silt						225	Interbedded, gray SILT and brown organic SILT; frozen Nbe, Vs, and Vx; 15% visible ice; lightweight; moist; ice is not visible.
7–13	S-4, S-5, S-6, S-7, S-8	ICE ML		21 26 40 33 36 33 34 40 45 50 50		Ice with soil inclusions						158, 165, 63, 138, 84	ICE with gray silt inculsions to SILT with ice inculsions; silt inculsions are primarily horizontal; silt content varies from 5 to 50%. - 5 to 30% soil from 7.0 to 10.0 feet - 50% soil from 10 to 11 feet - 40 to 50% soil from 11 to 12 feet - 60% soil from 12 to 13 feet
13–20	S-9, S-10, S-11, S-12	Vr Vs Vx	F4	70 52 75 78 55 87/4" 74 107 87 53 51 55	ML	Silt		6	94			50, 39, 73, 200	Gray SILT and brown organic SILT; frozen Vr, Vs, and Vx, visible ice 1 to 3 mm in size. - 40% visible ice in Sample S-9 - 20% visible ice in Sample S-10 - 40% visible ice from 15.3 to 16.2 feet in Sample S-11 - 10% visible ice from 16.2 to 16.3 feet in Sample S-11 - 40% visible ice in Sample S-12

Bottom of Boring at 20.0 ft
Boring Completed 28-Jul-2005

PID=(Cold/Hot) Photoionization Detector

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

EXPLORATION LOG

Project: Potential Relocation Sites, Kivalina, Alaska
Project No.: 31-1-01874-002

Date: 29-Jul-2005

Drilling Agency: ☐ Alaska District ☒ Other Discovery Drilling

Elevation Datum: ☐ MSL ☐ other

Location: (NAD27) Latitude: N67.81076 Longitude: W164.56284

Top of Hole Elevation:

Hole Number, Field: 05-3
Permanent:

Operator: Jordan Wininger

Inspector: Frank Wuttig

Type of Hole: ☐ other ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: Not encountered

Depth Drilled: 23.0 ft

Total Depth: 23.3 ft

Hammer Weight:	Split Spoon I.D:	Size and Type of Bit	Type of Equipment:	Type of Samples:
340 lb	2.5 in.	3 1/4" I.D. HSA and 6" SSA	CME 45 with cathead and rope	Drive and grab

Depth (ft)	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks (Surface: Tussocks)
0					PT	Peat.							Organics.
1		V	F4		ML OL	Silt							Gray SILT and brown organic SILT; increasing ice content with depth.
2–4	S-1	Vx	F4	5 9 16 20	ML	Silt						17	Gray SILT; frozen Vx; inclusions up to 20 mm in size; becoming brown below 5 feet. - 40% visible ice in Sample S-1 - up to 40% visible ice in Sample S-2
6–7	S-2			4 13 29								163	
7.5–8	S-3	Vc	F3	100/5" 100/7"	GM	Silty gravel with sand	47	18	34	1		15	Brown, silty, sandy GRAVEL; frozen Vc; 10 to 20% visible ice in Sample S-2.
10		Vc Nbn	S1		GW-GM	Well-graded gravel with silt and sand							Brown, trace to slightly silty, sandy GRAVEL; frozen Vc and Nbn; up to 10% visible ice filling pores. - Sample S-6 is a grab sample
13	S-4			100/4"			58	37	5	1.5		12	
18	S-5			100/3"								11	
19–20	S-6											10	
23	S-7			138/3"		Bedrock						8	LIMESTONE bedrock; drilling refusal.

Bottom of Boring at 23.3 ft
Boring Completed 29-Jul-2005

PID=(Cold/Hot) Photoionization Detector

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

EXPLORATION LOG

Project: Potential Relocation Sites, Kivalina, Alaska
Project No.: 31-1-01874-002

Date: 31 Jul-2005

Drilling Agency: ☐ Alaska District ☐ Other Discovery Drilling

Elevation Datum: ☐ MSL ☐ other

Location: (NAD27) Latitude: N67.81570 Longitude: W164.59783

Top of Hole Elevation:

Hole Number, Field: 05-4 Permanent:

Operator: Jordan Wininger

Inspector: Frank Wuttig

Type of Hole: ☐ other ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: Not enountered

Depth Drilled: 25.0 ft

Total Depth: 25.4

Hammer Weight:	Split Spoon I.D:	Size and Type of Bit	Type of Equipment:	Type of Samples:
340 lb	2.5 in.	3 1/4" I.D. HSA and 6" SSA	CME 45 with cathead and rope	Drive

Surface: nonsorted circle

Depth (ft)	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks
0			F4		ML	Silt							Brown SILT; moist; thawed.
2.7–3.4	S-1	Nbn Nbe	F4	5, 10, 15, 22	OL	Organic soil						42	Brown, organic SILT; frozen Nbn to Nbe.
3.4		ICE				Ice						160	ICE; white; opaque with horizontal lenses of clear ice; stained brown from 10 to 10.7 feet.
8–10	S-2			12, 22, 26, 68/5"									
10–12	S-3			23, 22, 50/5"									
12.4	S-4			40, 52, 48		Ice with soil inclusions						105	ICE; with inclusions of gray silt. - 50% soil in Sample S-4
14	S-5			38, 20, 48								194	- 30% soil in Sample S-5
14.4						Ice							ICE; white; opaque.
16.5		ICE ML				Ice with soil inclusions							ICE with inclusions of gray silt. - 40% silt in Sample S-6
18.5	S-6	Vs	F4	30, 42, 70	M	Silt		5	95			41	Gray SILT; frozen Vs, 1 to 3 mm lenses; 5% visible ice.
22.5		Nbn Vc	F2		SM	Silty sand							Brown, slightly silty to silty, gravelly, SAND; frozen Nbn and Vc; 5% visible ice filling voids; subangular to subrounded particles; (water sorted; alluvium or marine ?)
25	S-7			100/5"			14	73	13	1/2		15	

Bottom of Boring at 25.4
Boring Completed 31 Jul-2005

PID=(Cold/Hot) Photoionization Detector

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

EXPLORATION LOG

Project: Potential Relocation Sites, Kivalina, Alaska
Project No.: 31-1-01874-002

Date: 31-Jul-2005

Drilling Agency: ☐ Alaska District ☒ Other Discovery Drilling

Elevation Datum: ☐ MSL ☐ other

Location: (NAD27) Latitude: N67.82088 Longitude: W164.59229

Top of Hole Elevation:

Hole Number, Field: 05-5
Permanent:

Operator: Jordan Wininger

Inspector: Frank Wuttig

Type of Hole: ☐ other ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: Not encountered

Depth Drilled: 24.5 ft

Total Depth: 26 ft

Hammer Weight:	Split Spoon I.D:	Size and Type of Bit	Type of Equipment:	Type of Samples:
340 lb	2.5 in.	3 1/4" I.D. HSA and 6" SSA	CME 45 with cathead and rope	Drive

Surface: Tussocks, low-center polygon interior

Depth (ft)	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks
0					PT	Peat							Organics.
1		V	F4		ML OL	Silt							Organic SILT and ice-rich SILT; frozen.
3	S-1	ICE ML		15 15 21 25		Ice with soil inclusions							ICE with gray silt inclusions.
4		Vx Vs	F4		ML	Silt						117	Gray SILT; frozen Vx and irregular Vs; 30% visible ice.
5	S-2	ICE ML		14 20 20 20		Ice with soil inclusions						131	ICE with gray silt inclusions to SILT with ice inclusions; lenses up to 5 mm thick and inclusions up to 10 mm in size.
8	S-3	ICE		7 13 15 16		Ice							ICE; white; opaque; reticulate cracking pattern.
10	S-4			15 13 13 15									
12	S-5			13 17									
13.5	S-6			31 28									
15	S-7			31 50 24 30 50									
18	S-8			24 37									
19		Vr Vs	F4	45 45	ML	Silt						129	Grayish-brown SILT; trace sand and gravel; frozen Vr and Vs; 1 to 3 mm lenses and veins; 20 to 40% visible ice.
24.5	S-9			42				11	89			142	
25				75 44		Ice							ICE with grayish-brown silt inclusions; 0 to 20% soil.

Bottom of Boring at 26 ft
Boring Completed 31-Jul-2005

PID=(Cold/Hot) Photoionization Detector

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

EXPLORATION LOG

Project: Potential Relocation Sites, Kivalina, Alaska
Project No.: 31-1-01874-002

Date: 1-Aug-2005

Drilling Agency: ☐ Alaska District ☒ Other Discovery Drilling

Elevation Datum: ☐ MSL ☐ other

Location: (NAD27) Latitude: N67.82279 Longitude: W164.60881

Top of Hole Elevation:

Hole Number, Field:	Permanent:	Operator:	Inspector:
05-6		Jordan Wininger	Frank Wuttig

Type of Hole: ☐ other ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater:	Depth Drilled:	Total Depth:
Not encountered	25 ft	26 ft

Hammer Weight:	Split Spoon I.D:	Size and Type of Bit	Type of Equipment:	Type of Samples:
340 lb	2.5 in.	3 1/4" I.D. HSA and 6" SSA	CME 45 with cathead and rope	Drive

Surface: Edge of broad drainage, low-center polygon interior

Depth (ft)	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks
0		Nbe	F4		PT	Peat							Organics.
1					OL	Organic soil							Brown, organic SILT; frozen
2		Vx			PT	Peat							PEAT and organics with ice inclusions.
3	S-1			39 27 17								1779	
6		ICE ML				Ice with soil inclusions							ICE with gray silt and brown organic silt inclusions to ice with SILT inclusions. - 20% soil in Sample S-2 - 30 to 70% soil in Sample S-3 - generally horizontal structure to ice in S-3 with irregular lenses 1 to 5 mm thick
8	S-2			26 25 25								163	
12	S-3			11 30 35 30								157	
15		Vs Vr	F4		ML	Silt with sand							Gray and brown, slightly sandy to sandy SILT; trace gravel; frozen Vs and Vr; lenses and veins < 1mm thick; 3% visible ice; angular and subrounded particles; (colluvium).
18	S-4			34 38 48 48			6	13	81			33	
23		Nbn Nf Vc	PFS		SW-SM	Well-graded sand with silt and gravel							Brown, trace to slightly silty, gravelly SAND; frozen Nbn to Nf; trace Vc; less 1% visible ice; (alluvium or marine).
25	S-5			60 50			37	58	5	1.5		6	
26													Bottom of Boring at 26 ft Boring Completed 1-Aug-2005

PID=(Cold/Hot) Photoionization Detector

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

EXPLORATION LOG

Project: Potential Relocation Sites
Kivalina, Alaska
Project No.: 31-1-01874-002

Date: 1-Aug-2005

Drilling Agency: ☐ Alaska District ☒ Other Discovery Drilling

Elevation Datum: ☐ MSL ☐ other

Location: (NAD27) Latitude: N67.84528 Longitude: W164.73532

Top of Hole Elevation:

Hole Number, Field: 05-7 Permanent:

Operator: Jordan Wininger

Inspector: Frank Wuttig

Type of Hole: ☐ other ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: Not encountered

Depth Drilled: 8 ft

Total Depth: 8.3 ft

Hammer Weight:	Split Spoon I.D:	Size and Type of Bit	Type of Equipment:	Type of Samples:
340 lb	2.5 in.	3 1/4" I.D. HSA and 6" SSA	CME 45 with cathead and rope	Drive

Depth (ft)	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks
													Surface: Gravel covered
0		Vc	F2		GM	Silty gravel with sand							Brown, slightly silty to silty, sandy GRAVEL; moist; thawed; angular limestone fragments; (completely weathered, cryoturbated bedrock/colluvium) - frozen Vc with 5% visible ice below 5 feet
3	S-1			7 5 4 5								3	
6	S-2			16 34 65			46	40	14	1.5		10	
6.5						Bedrock							LIMESTONE; low strength when thawed; very closely jointed; silt fills joints; 5% visible ice in joints; highly weathered. - drilling refusal at 8.3 feet
8	S-3			50/3"								7	

Bottom of Boring at 8.3 ft
Boring Completed 1-Aug-2005

PID=(Cold/Hot) Photoionization Detector

Depth scale: 0–35 ft

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

EXPLORATION LOG

Project: Potential Relocation Sites, Kivalina, Alaska
Project No.: 31-1-01874-002

Date: 1-Aug-2005

Drilling Agency: ☐ Alaska District ☒ Other Discovery Drilling

Elevation Datum: ☐ MSL ☐ other

Location: (NAD27) Latitude: N67.84895 Longitude: W164.72621

Top of Hole Elevation:

Hole Number, Field: 05-8 Permanent:

Operator: Jordan Wininger

Inspector: Frank Wuttig

Type of Hole: ☐ other ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: Not encountered

Depth Drilled: 13 ft

Total Depth: 13.4 ft

Hammer Weight: 340 lb

Split Spoon I.D: 2.5 in.

Size and Type of Bit: 3 1/4" I.D. HSA and 6" SSA

Type of Equipment: CME 45 with cathead and rope

Type of Samples: Drive

Surface: Tussocks, faint polygonal pattern

Depth (ft)	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks
0					PT	Peat							Organics.
1		V	F4		OL	Organic soil							Brown, organic SILT; ice rich.
2–4	S-1	Vx Vs	F4	22 31	ML	Silt						65	Gray, slightly sandy and gravelly SILT; frozen Vx and Vs; ice inclusions and lenses up to 6 mm in size; 30 to 40% visible ice.
4–5	S-1	Vc Vr Vx	F4	24 28	ML	Silt with sand						44	Brown, slightly gravelly, sandy SILT; frozen Vc, Vr, and Vx; 1 mm lenses; angular to subrounded particles; 15% visible ice.
5–11.5	S-2	Nbn Vs Vc	F3	21 35 35	SM	Silty sand	7	68	25	1		21	Brown, slightly gravelly, silty, SAND; frozen Nbn/Nbe, Vs and Vc; lenses less than 1 mm thick; occasional cobbles. - 3% visible ice in Sample S-2 - no visible ice in Sample S-3
8	S-3			132/3								14	
11.5–13.4	S-4	Nbn Nf		175/1		Bedrock							SILTSTONE; very low strength; black; iron oxide stained; very closley jointed; frozen Nbn/Nf; no visible ice; moderatley weathered. - drilling refusal at 13.4 feet
13	S-5			200/5								4	

Bottom of Boring at 13.4 ft
Boring Completed 1-Aug-2005

PID=(Cold/Hot) Photoionization Detector

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GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

EXPLORATION LOG

Project: Potential Relocation Sites
Kivalina, Alaska
Project No.: 31-1-01874-002

Date: 2-Aug-2005

Drilling Agency: ☐ Alaska District ☒ Other Discovery Drilling

Elevation Datum: ☐ MSL ☐ other

Location: (NAD27) Latitude: N67.84718 Longitude: W164.73122

Top of Hole Elevation:

Hole Number, Field: 05-9 Permanent:

Operator: Jordan Wininger

Inspector: Frank Wuttig

Type of Hole: ☐ other ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: Not encountered

Depth Drilled: 8 ft

Total Depth: 8.2 ft

Hammer Weight:	Split Spoon I.D:	Size and Type of Bit	Type of Equipment:	Type of Samples:
340 lb	2.5 in.	3 1/4" I.D. HSA and 6" SSA	CME 45 with cathead and rope	Drive

Surface: Tussocks and scattered nonsorted circles

Depth (ft)	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks
0					PT	Peat							Organics.
1			F4		OL	Organic soil							Organic SILT; moist.
2		Nbe	F4		ML	Silt							Brown, slightly sandy to sandy SILT, trace clay; moist.
2.5		Vs	F4		OL	Organic soil							Brown, organic SILT; frozen Nbe.
3	S-1	Vx	F3	3 8 21 35	GM	Silty gravel with sand	50	24	26	1		29	Gray, silty, sandy GRAVEL; frozen Vs and Vx; 50% visible ice; angular particles.
4		Vs Vx Vc	F3		GM	Silty gravel with sand							Brown, silty, sandy GRAVEL; frozen Vs, Vx, and Vc; lenses up to 3 mm thick; up to 25% visible ice.
5–8.2	S-2	Nbn Nf		162/4"		Bedrock						4	SILTSTONE; very low strength; black; iron oxide stained; very closely jointed; frozen Nbn/Nf; no visible ice. - drilling refusal at 8.2 feet.
8	S-3			100/2"									

Bottom of Boring at 8.2 ft
Boring Completed 2-Aug-2005

PID=(Cold/Hot) Photoionization Detector

BASED ON USCOE NPA FORM 19-E

PROJECT: Potential Relocation Sites Kivalina, Alaska

Hole Number: Field: 05-9

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

EXPLORATION LOG

Project: Potential Relocation Sites, Kivalina, Alaska
Project No.: 31-1-01874-002

Date: 2-Aug-2005

Drilling Agency: ☐ Alaska District ☒ Other Discovery Drilling

Elevation Datum: ☐ MSL ☐ other

Location: (NAD27) Latitude: N67.84334 Longitude: W164.73958

Top of Hole Elevation:

Hole Number, Field: 05-10 Permanent:

Operator: Jordan Wininger

Inspector: Frank Wuttig

Type of Hole: ☐ other ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: Not encountered

Depth Drilled: 19.5 ft

Total Depth: 21.5 ft

Hammer Weight	Split Spoon I.D	Size and Type of Bit	Type of Equipment	Type of Samples
340 lb	2.5 in.	3 1/4" I.D. HSA and 6" SSA	CME 45 with cathead and rope	Drive

Surface: Tussocks, faint polygonal pattern

Depth (ft)	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks
0–0.4					PT	Peat							Organics.
0.4–2.0		V	F4		ML OL	Silt							Gray SILT and brown organic SILT; frozen below 1.0 foot with 15% visible ice.
2.0–3.6	S-1	Vs Vx	F4	12 23 25 35	ML	Silt						95	Gray SILT; frozen Vs and Vx; trace organics; lenses up to 5 mm thick. - 30% visible ice from 2.0 to 3.0 feet - 10% visible ice from 3.0 to 3.6 feet
3.6–4.3		Vs	F4		OL	Organic soil						83	Brown, organic SILT; frozen Vs; lenses < 1mm thick; 50% visible ice.
4.3–10.0	S-2	Vs Vr	F4	14 21 23 10	ML	Silt						137	Gray SILT; frozen Vs and Vr; 1 to 3 mm lenses; 15% visible ice aside from noted ice. - 25 mm ice lens at 5.4 and 5.7 feet - 40 mm ice lens and 6.4 feet - massive ice from 5.7 to 6.3 feet - 20% visible ice from 9.5 to 10.0 feet in Sample S-3
10.0–15.3	S-3	ICE ML		17 44 42		Ice with soil inclusions						123	ICE with gray silt inclusions.
15.3–20.2	S-4	Vs Vx Vr	F4	32 55 74 75	ML	Silt		6	95			95	Gray SILT; occasional zones of brown organic silt; frozen Vs, Vx, and Vr; ice lenses < 3mm thick; 15 to 20% visible ice. - zone with 40% visible ice from 15.8 to 16.0 feet.
20.2–21.5	S-5			20 60 75		Ice with soil inclusions						114	ICE with silt inclusions and occasional layers of silt one inch thick; 20 to 30% soil.

Bottom of Boring at 21.5 ft
Boring Completed 2-Aug-2005

PID=(Cold/Hot) Photoionization Detector

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

EXPLORATION LOG

Project:	Potential Relocation Sites, Kivalina, Alaska
Project No.:	31-1-01874-002
PAGE 1 OF 1	Date: 2-Aug-2005
Drilling Agency:	☐ Alaska District ☒ Other Discovery Drilling
Elevation Datum:	☐ MSL ☐ other
Location: (NAD27)	Latitude: N67.84513 Longitude: W164.72507
Top of Hole Elevation:	
Hole Number, Field:	05-11
Permanent:	
Operator:	Jordan Wininger
Inspector:	Frank Wuttig
Type of Hole:	☐ other ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer
Depth to Groundwater:	Not encountered
Depth Drilled:	10 ft
Total Depth:	10.5 ft
Hammer Weight:	340 lb
Split Spoon I.D:	2.5 in.
Size and Type of Bit	3 1/4" I.D. HSA and 6" SSA
Type of Equipment:	CME 45 with cathead and rope
Type of Samples:	Drive

Surface: Tussocks; faint nonsorted circles

Depth (ft)	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks
0–1			F4		PT	Peat and organic soil							Organics and organic silt.
1–3		ICE CL			OL	Ice with soil inclusions							ICE with inclusions of gravelly, sandy silt; 50 to 60% visible ice.
3–4.5	S-1	Vr Vs Vx	F4	11 27 22	CL	Sandy lean clay with gravel	37	7	56	2		33	Gray, slightly sandy to sandy, gravelly, silty CLAY; frozen Vr, Vs, and Vx; ice 3 mm in size; 15 to 20% visible ice.
4.5–8	S-2		F4	30 38 35	CL	Sandy lean clay	6	33	61	1		29	Gray, slightly gravelly, sandy, silty CLAY; frozen Nbe; no visible ice; (residual soil/completely weathered bedrock)
8–10.5	S-3, S-4			14 40 80		Bedrock						22, 17	SILTSTONE/CLAYSTONE; very low strength; black; iron oxide stained; very closely jointed; visible ice in joints; moderately to highly weathered. - 10% visible ice in Sample S-3 - 3% visible ice in Sample S-4

Bottom of Boring at 10.5 ft
Boring Completed 2-Aug-2005

PID=(Cold/Hot) Photoionization Detector

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

EXPLORATION LOG

Project: Potential Relocation Sites, Kivalina, Alaska
Project No.: 31-1-01874-002
Date: 3-Aug-2005

Drilling Agency: ☐ Alaska District ☒ Other Discovery Drilling
Elevation Datum: ☐ MSL ☐ other
Location: (NAD27) Latitude: N67.84685 Longitude: W164.72081
Top of Hole Elevation:

Hole Number, Field: 05-12
Permanent:
Operator: Jordan Wininger
Inspector: Frank Wuttig

Type of Hole: ☐ other ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer
Depth to Groundwater: Not encountered
Depth Drilled: 8 ft
Total Depth: 8.5 ft

Hammer Weight:	Split Spoon I.D:	Size and Type of Bit	Type of Equipment:	Type of Samples:
340 lb	2.5 in.	3 1/4" I.D. HSA and 6" SSA	CME 45 with cathead and rope	Drive

Description and Remarks — Surface: Tussocks; faint, nonsorted circles

Depth (ft)	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks
0			F4		PT	Peat							Organics.
0–2.5					ML	Silt							Brown, slightly sandy SILT; moist.
2.5–4.6	S-1	Vx Vs	F3	40 20 30 40	GM	Silty gravel with sand	29	28	43	3/4		63, 22	Brown, sandy, gravelly SILT to silty, sandy GRAVEL; frozen Vx and Vs; angular particles. - 40 to 50% visible ice from 2.5 to 4.0 feet - 30% visible ice from 4.0 to 4.6 feet
4.6–8.5	S-2, S-3			134/6", 120/6"		Bedrock						14, 6	SILTSTONE: very low strength; gray; very closely spaced joints; slightly cryoturbated near top; ice filling some joints; completely to highly weathered. - frozen Nbn with less than 3% visible ice in Sample S-2 - frozen Nf with no visible ice in Sample S-3

Bottom of Boring at 8.5 ft
Boring Completed 3-Aug-2005

PID=(Cold/Hot) Photoionization Detector

BASED ON USCOE NPA FORM 19-E

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

EXPLORATION LOG

Project: Potential Relocation Sites, Kivalina, Alaska
Project No.: 31-1-01874-002

Date: 3-Aug-2005

Drilling Agency: ☐ Alaska District ☒ Other Discovery Drilling

Elevation Datum: ☐ MSL ☐ other

Location: (NAD27) Latitude: N67.85083 Longitude: W164.73225

Top of Hole Elevation:

Hole Number, Field: 05-13 Permanent:

Operator: Jordan Wininger

Inspector: Frank Wuttig

Type of Hole: ☐ other ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: Not encountered

Depth Drilled: 14.5 ft

Total Depth: 15 ft

Hammer Weight	Split Spoon I.D	Size and Type of Bit	Type of Equipment	Type of Samples
340 lb	2.5 in.	3 1/4" I.D. HSA and 6" SSA	CME 45 with cathead and rope	Drive

Surface: Tussocks

Depth (ft)	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks
0–1					PT	Peat							Organics.
1–7	S-1 (2.5–4.5), S-2 (4.5–7)	Vx Vs	F4	S-1: 4, 8, 18, 20; S-2: 8, 16, 19, 35	ML	Sandy silt		31	69			108 (S-1); 77 (S-2)	Gray, trace to slightly gravelly, sandy SILT; occasional thin peat and ice layers as noted; frozen Vx and Vs; ice lenses up to 5 mm thick and inclusions up to 7 mm in size; angular particles. - 40% visible ice from 2.5 to 3.5 feet in Sample S-1 - ice with soil inclusions (20%) from 3.5 to 3.8 feet - frozen peat layer from 3.1 to 3.2 and 4.0 to 4.2 feet - 40% visible ice from 4.2 to 4.5 feet - 30% to 40% visible ice from 4.5 to 7.2 feet
7–11.5	S-3 (7–9)	ICE		20, 21, 24, 25		Ice							ICE; white; opaque; reticulate crack pattern.
11.5–14.2	S-4 (13–14.2)			20, 38, 65, 68		Bedrock						39	SILTSTONE; very low strength when thawed; brown and black; frozen Vx; inclusions up to 10 mm in size; 10% visible ice, completely weathered.
14.2–15	S-5					Bedrock						20	SILTSTONE; very low strength when thawed; frozen Vx; 5 to 15% visible ice; completely to highly weathered.

Bottom of Boring at 15 ft
Boring Completed 3-Aug-2005

PID=(Cold/Hot) Photoionization Detector

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

EXPLORATION LOG

Project:	Potential Relocation Sites, Kivalina, Alaska
Project No.:	31-1-01874-002
PAGE 1 OF 1	Date: 4-Aug-2005
Drilling Agency:	☐ Alaska District ☒ Other Discovery Drilling
Elevation Datum:	☐ MSL ☐ other
Location: (NAD27)	Latitude: N67.84881 Longitude: W164.73717
Top of Hole Elevation:	
Hole Number, Field:	05-14
Permanent:	
Operator:	Jordan Wininger
Inspector:	Frank Wuttig
Type of Hole:	☐ other ☐ Test Pit ☒ Auger Hole ☐ Monitoring Well ☐ Piezometer
Depth to Groundwater:	Not encountered
Depth Drilled:	13 ft
Total Depth:	14 ft
Hammer Weight:	340 lb
Split Spoon I.D:	2.5 in.
Size and Type of Bit	3 1/4" I.D. HSA and 6" SSA
Type of Equipment:	CME 45 with cathead and rope
Type of Samples:	Drive

Surface: Tussocks; faint nonsorted stripes

Depth (ft)	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks
0–0.5					PT	Peat							Organics.
0.5–1.5		Nbe			OL	Organic soil							Brown, organic SILT; frozen.
1.5–3.2		Vx			ML	Silt with sand							Gray, slightly clayey, gravelly sandy SILT; frozen Vx; 15 to 20% visible ice.
3.2–4.3	S-1 (2.5–4)	ICE ML		42 27 27		Ice with soil inclusions						60	ICE with grayish-brown, slightly clayey, gravelly, sandy SILT; 50 to 60% visible ice.
4.3–6.5	S-2 (5–6.5)	Vs Vx		16 30 32	CL	Sandy lean clay		34	66			36	Gray, sandy, silty CLAY; frozen Vs and Vx; lenses < 3mm thick; 20% visible ice; (colluvium).
6.5–10.2	S-3 (9–11)			16 53 53 63		Bedrock						19	SILTSTONE/CLAYSTONE very low strength when thawed; gray; frozen Vr; 1 to 6 mm irregular ice veins from 9.5 to 10.1 feet; completely to highly weathered.
10.2–14	S-4 (12.5–14)			70 60		Bedrock						18, 8	SILTSTONE/CLAYSTONE; low strength when thawed; gray; very closely jointed, moderatley to highly weathered; frozen Nbn, Nf, and Vx. - frozen Vx (< 5 mm) with 5% visible ice from 10.2 to 11.0 feet - frozen Nbn/Nf with no visible ice below 11 feet

Bottom of Boring at 14 ft
Boring Completed 4-Aug-2005

PID=(Cold/Hot) Photoionization Detector

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

EXPLORATION LOG

Project: Potential Relocation Sites
Kivalina, Alaska
Project No.: 31-1-01874-002

Date: 30-Jul-2005

Drilling Agency: ☐ Alaska District ☒ Other Shannon & Wilson

Elevation Datum: ☐ MSL ☐ other

Location: (NAD27) Latitude: N67.81055 Longitude: W164.56329

Top of Hole Elevation:

Hole Number, Field: TP-05-1
Permanent:

Operator:

Inspector: Frank Wuttig

Type of Hole: ☐ other ☒ Test Pit ☐ Auger Hole ☐ Monitoring Well ☐ Piezometer

Depth to Groundwater: Not encountered

Depth Drilled:

Total Depth: 4 ft

Hammer Weight:

Split Spoon I.D:

Size and Type of Bit

Type of Equipment: Shovel

Type of Samples: Grab

Depth (ft)	Lithology	Sample	Frozen ASTM D-4083	Frost Class. TM 5-822-5	Blow Count	Symbol	Classification ASTM: D 2487 or D 2488	%Gravel	%Sand	%Fines	Max Size (in)	PID (ppm)	% Water	Description and Remarks
														Surface: Cutbank of Kivalina River
0				F4		PT	Peat							Organics.
1				F2		ML	Silt							Brown SILT with increasing gravel and sand content with depth; thawed.
2				S1			Silty gravel with sand							Brown, silty, sandy GRAVEL; subangular to subrounded particles; maximum particle size is 2 inches; thawed; moist
4		S-1					Well-graded gravel with silt and sand	63	32	5	3			Brown, trace to slightly silty, sandy GRAVEL; subangular to subrounded particles; maximum particle size is 3 inches; thawed; moist.

Bottom of Boring at 4 ft
Boring Completed 30-Jul-2005

PID=(Cold/Hot) Photoionization Detector

Depth scale: 0–35 ft

BASED ON USCOE NPA FORM 19-E

PROJECT: Potential Relocation Sites
Kivalina, Alaska

Hole Number:
Field: TP-05-1

APPENDIX B

Laboratory Test Results

Table B1
Summary of Laboratory Test Results

Sample Identification	Tested Depth (ft)	Moisture Content (%)	Grain Size Analysis				Atterberg Limits			Unit Weight		Organic Content (%)	USCS
			Gravel Content (%)	Sand Content (%)	Fines Content (%)	Content Finer Than 0.02 mm (%)	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index	Total (pcf)	Dry (pcf)		
Boring 05-1													
Sample S-1	2.5-4.0												
S-2	5.0-6.5												
S-3	6.5-8.0												
S-4	8.0-9.5												
S-5	9.5-11.0												
S-6	11.0-12.0												
S-7	12.0-13.2												
S-8	13.2-13.9												
S-9	13.9-14.5												
S-10	14.5-16.0												
S-11	16.0-17.0												
S-12	17.0-19.5												
S-13	19.5-21.0												
S-14	21.0-22.5												
Boring 05-2													
Sample S-1	2.0-3.5	162											
S-2	2.2-2.8											43.8	
S-3	5.0-6.5	225											
S-4	7.0-8.5	158											

Test Methods:
Moisture Content: ASTM D 2216
Grain Size Analysis: ASTM D 1140/D 422
Atterberg Limits: ASTM D 4318
Unit Weight: Shannon & Wilson Method
Organic Content: ASTM D 2974

Explanation:
Gravel: particles larger than the No. 4 sieve and smaller than 3 inches
Sand: particles larger than the No. 200 sieve and smaller than the No. 4 sieve
Fines: particles smaller than the No. 200 sieve
NP: not plastic

Table B2
Summary of Laboratory Test Results

			Grain Size Analysis				Atterberg Limits			Unit Weight			
Sample Identification	**Tested Depth (ft)**	**Moisture Content (%)**	**Gravel Content (%)**	**Sand Content (%)**	**Fines Content (%)**	**Content Finer Than 0.02 mm (%)**	**Plastic Limit (%)**	**Liquid Limit (%)**	**Plasticity Index**	**Total (pcf)**	**Dry (pcf)**	**Organic Content (%)**	**USCS**
Boring 05-2													
Sample S-5	8.5-10.0	165											
S-6	10.0-11.0	63											
S-7	11.0-12.0	138											
S-8	12.0-13.0	84											
S-9	13.0-14.0	50		6	94	62	NP					7.2	ML
S-10	14.0-15.3	39										8.8	
S-11	16.2-16.8	73											
S-12	18.5-20.0	200											
Boring 05-3													
Sample S-1	2.0-4.0	17											
S-2	6.0-7.3	163											
S-3	8.0-8.6	15	47	18	34								GM
S-4	13.0-13.3	12	58	37	5								GW-GM
S-5	18.0-18.3	11											
S-6	18.0-23.0	10											
S-7	23.0-23.3	8											
Boring 05-4													
Sample S-1a	2.5-2.7	42											
S-1b	2.7-3.1	160											

Test Methods:
Moisture Content: ASTM D 2216
Grain Size Analysis: ASTM D 1140/D 422
Atterberg Limits: ASTM D 4318
Unit Weight: Shannon & Wilson Method
Organic Content: ASTM D 2974

Explanation:
Gravel: particles larger than the No. 4 sieve and smaller than 3 inches
Sand: particles larger than the No. 200 sieve and smaller than the No. 4 sieve
Fines: particles smaller than the No. 200 sieve
NP: not plastic

Table B3
Summary of Laboratory Test Results

			Grain Size Analysis				Atterberg Limits			Unit Weight			
Sample Identification	Tested Depth (ft)	Moisture Content (%)	Gravel Content (%)	Sand Content (%)	Fines Content (%)	Content Finer Than 0.02 mm (%)	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index	Total (pcf)	Dry (pcf)	Organic Content (%)	USCS
Boring 05-4													
Sample S-2	8.0-9.9												
S-3	10.0-11.4												
S-4	12.4-13.5	105											
S-5	13.5-14.0	194											
S-6	18.5-19.5	41		5	95	66	NP			92.7	65.7		ML
S-7	25.0-25.4	15	14	73	13								SM
Boring 05-5													
Sample S-1	4.0-4.5	117											
S-2	5.0-7.0	131											
S-3	8.0-10.0												
S-4	10.0-12.0												
S-5	12.0-13.5												
S-6	13.5-15.0												
S-7	15.0-16.5												
S-8	19.0-20.0	129											
S-9	24.5-25.0	142		11	89	64							ML
Boring 05-6													
Sample S-1	2.5-4.0	1779											
S-2	8.0-9.0	163											

Test Methods:
Moisture Content: ASTM D 2216
Grain Size Analysis: ASTM D 1140/D 422
Atterberg Limits: ASTM D 4318
Unit Weight: Shannon & Wilson Method
Organic Content: ASTM D 2974

Explanation:
Gravel: particles larger than the No. 4 sieve and smaller than 3 inches
Sand: particles larger than the No. 200 sieve and smaller than the No. 4 sieve
Fines: particles smaller than the No. 200 sieve
NP: not plastic

Table B4
Summary of Laboratory Test Results

Sample Identification	Tested Depth (ft)	Moisture Content (%)	Grain Size Analysis: Gravel Content (%)	Sand Content (%)	Fines Content (%)	Content Finer Than 0.02 mm (%)	Atterberg Limits: Plastic Limit (%)	Liquid Limit (%)	Plasticity Index	Unit Weight: Total (pcf)	Dry (pcf)	Organic Content (%)	USCS
Boring 05-6													
Sample S-3	12.0-15.0	157											
S-4	18.0-20.0	33	6	13	81	60	NP			104.3	78.4		ML
S-5	25.0-26.0	6	37	58	5								SW-SM
Boring 05-7													
Sample S-1	2.5-4.5	3											
S-2	5.5-7.0	10	46	40	14	11	NP						GM
S-3	8.0-8.3	7											
Boring 05-8													
Sample S-1a	2.5-3.6	65											
S-1b	3.6-4.5	44											
S-2	5.0-6.5	21	7	68	25	22	NP			117.2	96.8		SM
S-3	8.0-8.3	14											
S-4	11.5-11.6												
S-5	13.0-13.4	4											
Boring 05-9													
Sample S-1	3.0-4.0	29	50	24	26	21	31	25	5	111.3	86.6		GM
S-2	5.5-5.9	4								117.2	96.8		
S-3	8.0-8.2												

Test Methods:
Moisture Content: ASTM D 2216
Grain Size Analysis: ASTM D 1140/D 422
Atterberg Limits: ASTM D 4318
Unit Weight: Shannon & Wilson Method
Organic Content: ASTM D 2974

Explanation:
Gravel: particles larger than the No. 4 sieve and smaller than 3 inches
Sand: particles larger than the No. 200 sieve and smaller than the No. 4 sieve
Fines: particles smaller than the No. 200 sieve
NP: not plastic

Table B5
Summary of Laboratory Test Results

Sample Identification	Tested Depth (ft)	Moisture Content (%)	Grain Size Analysis: Gravel Content (%)	Sand Content (%)	Fines Content (%)	Content Finer Than 0.02 mm (%)	Atterberg Limits: Plastic Limit (%)	Liquid Limit (%)	Plasticity Index	Unit Weight: Total (pcf)	Dry (pcf)	Organic Content (%)	USCS
Boring 05-10													
Sample S-1a	3.0-3.6	95											
S-1b	3.6-4.0	83											
S-2	4.5-6.5	137											
S-3	9.5-10.0	123											
S-4	15.3-16.5	95		6	95	62	NP			80.3	41.2		ML
S-5	19.5-20.2	114											
Boring 05-11													
Sample S-1	3.1-4.0	33	37	7	56	52	37	24	13	102.1	76.7		CL
S-2	5.0-6.5	29	6	33	61	57	35	26	9	109.3	84.9		CL
S-3	9.0-10.0	22											
S-4	10.0-10.5	17											
Boring 05-12													
Sample S-1	2.5-4.0	63	29	28	43	36	NP			76.4	36.7		ML
S-2a	4.2-4.6	22											
S-2b	4.6-5.5	14											
S-3	8.0-8.5	6											
Boring 05-13													
Sample S-1	2.5-3.5	108		31	69	55	NP						ML
S-2	5.0-7.0	77											

Test Methods:
Moisture Content: ASTM D 2216
Grain Size Analysis: ASTM D 1140/D 422
Atterberg Limits: ASTM D 4318
Unit Weight: Shannon & Wilson Method
Organic Content: ASTM D 2974

Explanation:
Gravel: particles larger than the No. 4 sieve and smaller than 3 inches
Sand: particles larger than the No. 200 sieve and smaller than the No. 4 sieve
Fines: particles smaller than the No. 200 sieve
NP: not plastic

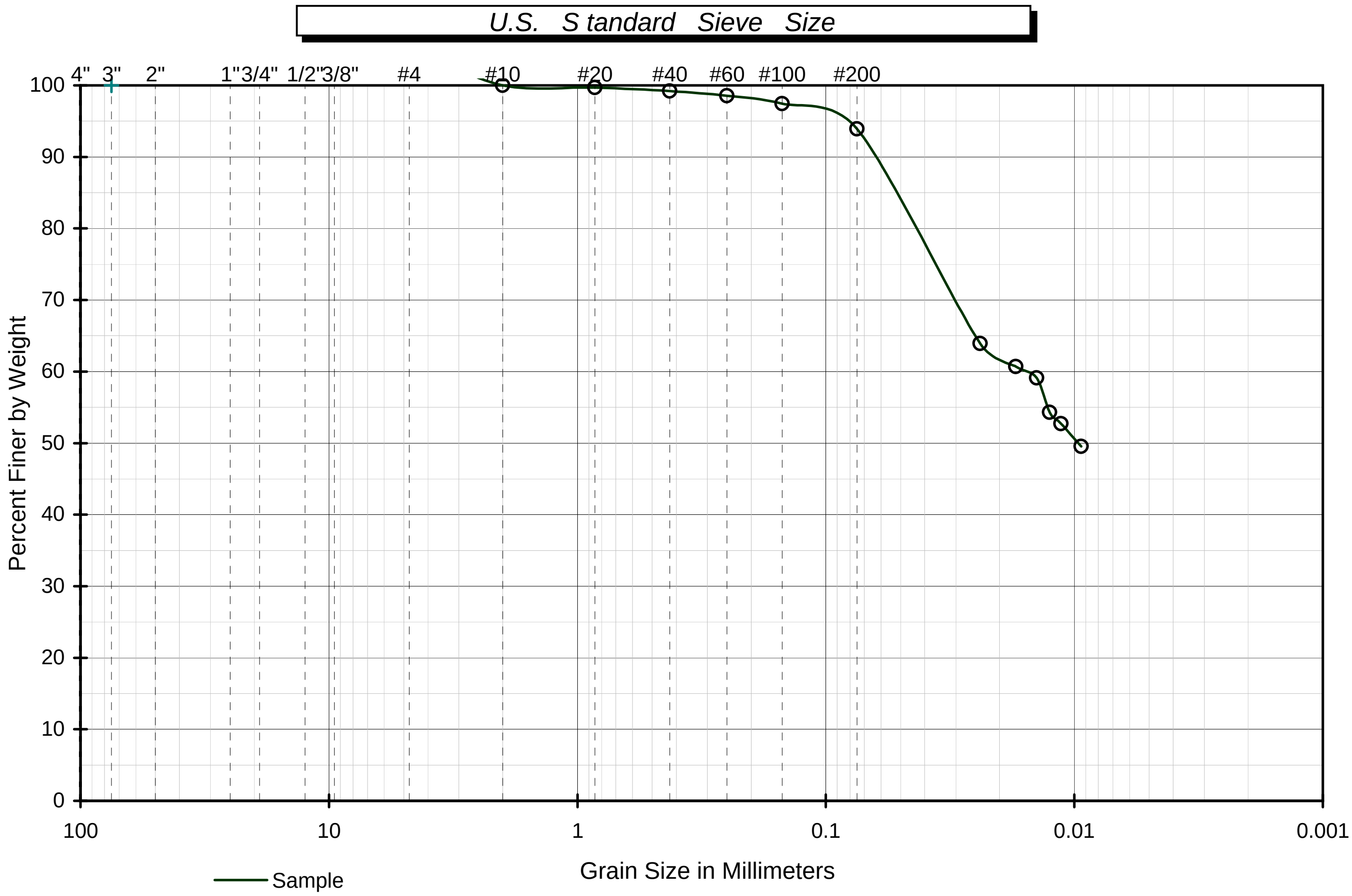
Table B6
Summary of Laboratory Test Results

Sample Identification	Tested Depth (ft)	Moisture Content (%)	Grain Size Analysis: Gravel Content (%)	Sand Content (%)	Fines Content (%)	Content Finer Than 0.02 mm (%)	Atterberg Limits: Plastic Limit (%)	Liquid Limit (%)	Plasticity Index	Unit Weight: Total (pcf)	Dry (pcf)	Organic Content (%)	USCS
Boring 05-13													
Sample S-3	7.2-9.0												
S-4	13.0-14.2	39											
S-5	14.5-15.0	20											
Boring 05-14													
Sample S-1	3.2-4.3	60											
S-2	5.0-6.5	36		34	66	56	32	24	8	107.7	79.4		CL
S-3a	9.5-10.2	19											
S-3b	10.2-11.0	18											
S-4	13.0-14.0	8											
Test Pit													
TP-05-1													
Sample S-1	3.5-4.0		63	32	5	4							GW-GM

Test Methods:
Moisture Content: ASTM D 2216
Grain Size Analysis: ASTM D 1140/D 422
Atterberg Limits: ASTM D 4318
Unit Weight: Shannon & Wilson Method
Organic Content: ASTM D 2974

Explanation:
Gravel: particles larger than the No. 4 sieve and smaller than 3 inches
Sand: particles larger than the No. 200 sieve and smaller than the No. 4 sieve
Fines: particles smaller than the No. 200 sieve
NP: not plastic

GRAIN SIZE DISTRIBUTION



*Unified Soil Classification**

Silt (ML)

Parameter	Grain Size (mm)**
D10	nv
D16	nv
D30	nv
D50	0.010
D60	0.016
D84	0.051

** nv - no value (insufficient data)

Cu = nv
Cc = nv

Sieve Size	Percent Passing by Weight	Hydrometer Grain Size (mm)	Hydrometer % Passing by Weight
4"		0.0239	**63.9**
3"		0.0172	**60.7**
2.5"		0.0142	**59.1**
2"		0.0126	**54.3**
1.5"		0.0113	**52.7**
1"		0.0094	**49.5**
3/4"			
1/2"			
3/8"			
#4			
#10	**100**		
#20	**100**		
#40	**99**		
#60	**99**		
#100	**97**		
#200	**93.9**		
0.02mm	**62.4**		

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION
D422/D1140
Boring 05-2, Sample S-9

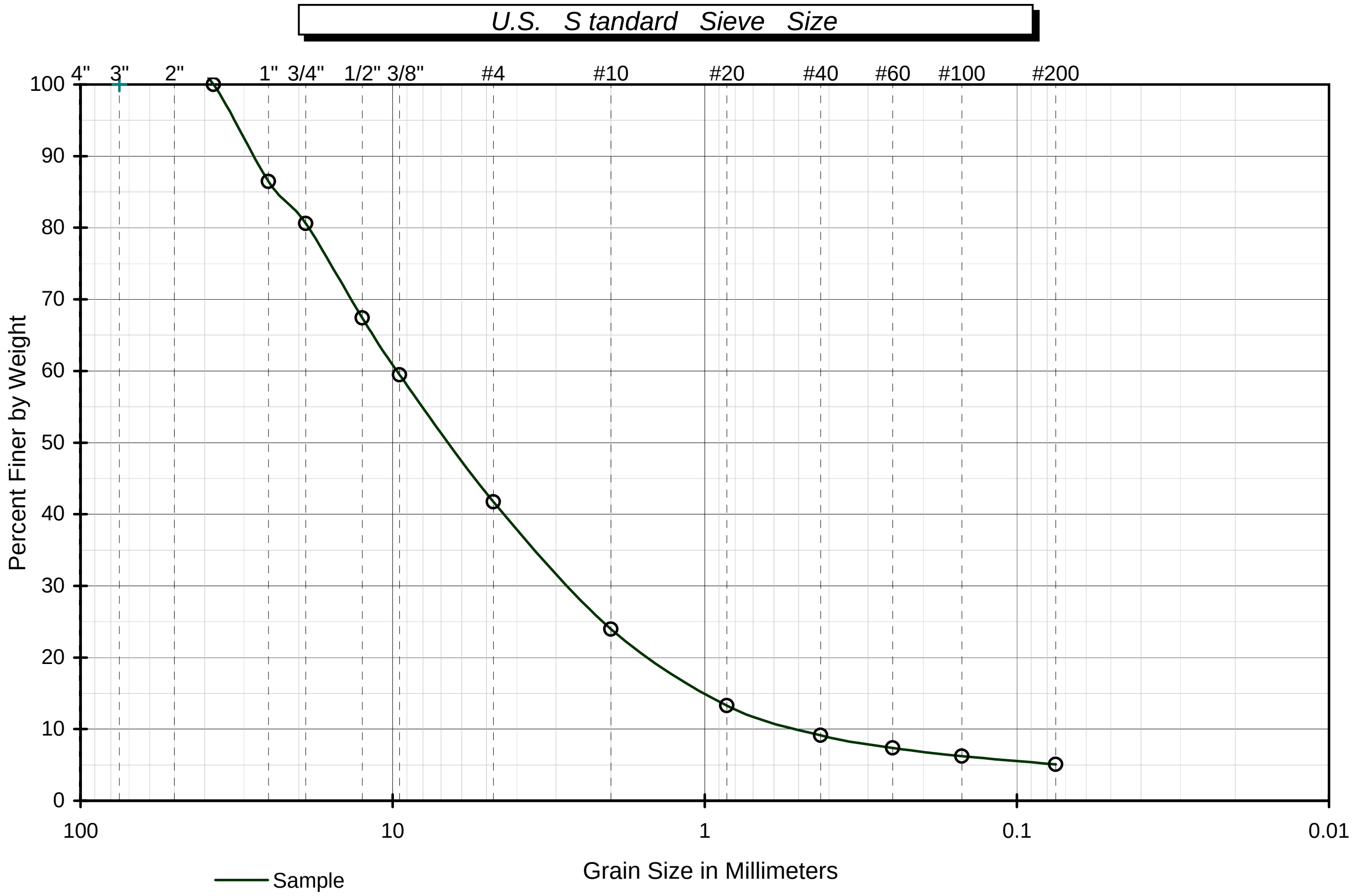
2005 31-1-01874-002

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Figure B1

* - Unified soil classification in general accordance with ASTM D2487

GRAIN SIZE DISTRIBUTION



*Unified Soil Classification**

Well graded gravel with sand and silt (GW-GM)

Sieve Size	Percent Passing by Weight
4"	
3"	
2.5"	
2"	
1.5"	100
1"	86
3/4"	81
1/2"	67
3/8"	59
#4	42
#10	24
#20	13
#40	9
#60	7
#100	6
#200	5.1
0.02mm	

Parameter	Grain Size (mm)**
D10	0.492
D16	1.056
D30	2.684
D50	6.562
D60	9.680
D84	22.299

** nv - no value (insufficient data)

Cu = 19.7
Cc = 1.5

* - Unified soil classification in general accordance with ASTM D2487

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION
C136/C117

Boring 05-3, Sample S-4

2005 31-1-01874-002

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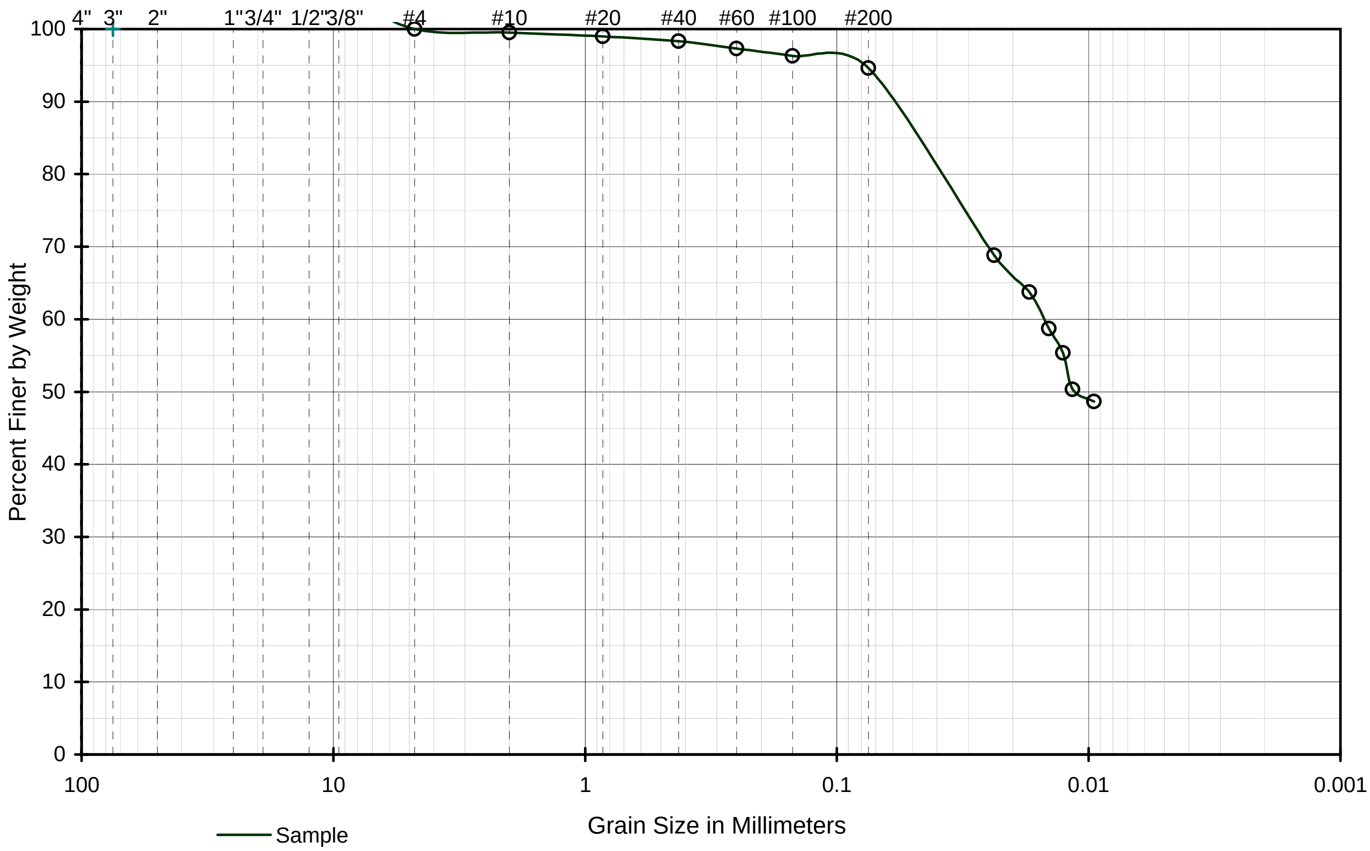
Figure B2

GRAIN SIZE DISTRIBUTION

U.S. Standard Sieve Size



*Unified Soil Classification**

Silt (ML)

Sieve Size	Percent Passing by Weight	Hydrometer Grain Size (mm)	Hydrometer % Passing by Weight
4"		0.0237	**68.8**
3"		0.0172	**63.8**
2.5"		0.0144	**58.7**
2"		0.0127	**55.4**
1.5"		0.0116	**50.3**
1"		0.0095	**48.7**
3/4"			
1/2"			
3/8"			
#4	**100**		
#10	**99**		
#20	**99**		
#40	**98**		
#60	**97**		
#100	**96**		
#200	**94.6**		
0.02mm	**66.4**		

Parameter	*Grain Size (mm)***
D10	nv
D16	nv
D30	nv
D50	0.011
D60	0.015
D84	0.047

** nv - no value (insufficient data)

Cu = nv

Cc = nv

* - Unified soil classification in general accordance with ASTM D2487

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION

D422/D1140

Boring 05-4, Sample S-6

2005 | 31-1-01874-002

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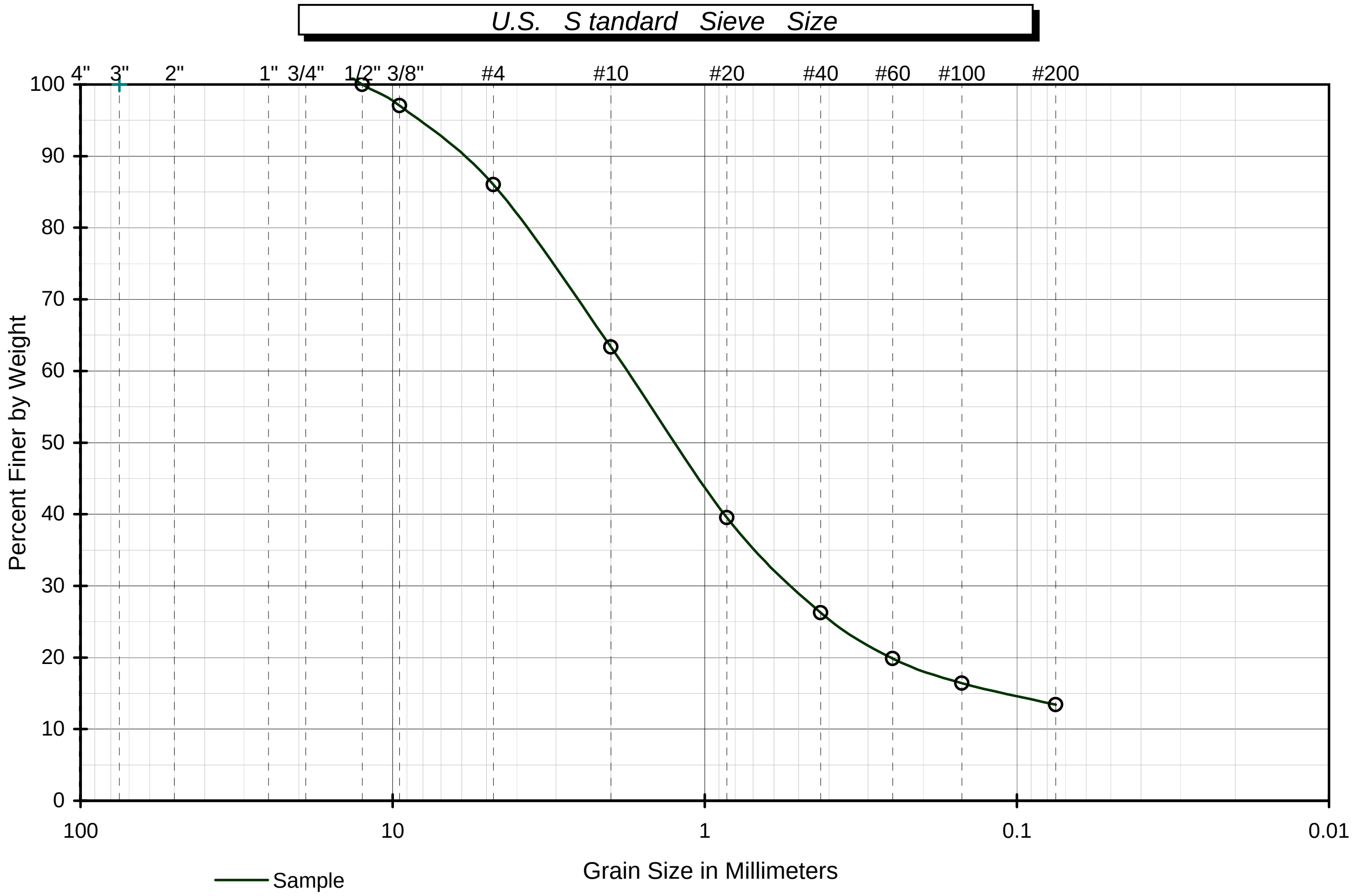
Figure B3

GRAIN SIZE DISTRIBUTION



*Unified Soil Classification**

Silty sand (SM)

Sieve Size	Percent Passing by Weight
4"	
3"	
2.5"	
2"	
1.5"	
1"	
3/4"	
1/2"	100
3/8"	97
#4	86
#10	63
#20	40
#40	26
#60	20
#100	16
#200	13.4
0.02mm	

Parameter	*Grain Size (mm)***
D10	nv
D16	0.136
D30	0.517
D50	1.238
D60	1.772
D84	4.397

** nv - no value (insufficient data)

Cu = nv

Cc = nv

* - Unified soil classification in general accordance with ASTM D2487

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION

C136/C117

Boring 05-4, Sample S-7

2005 | 31-1-01874-002

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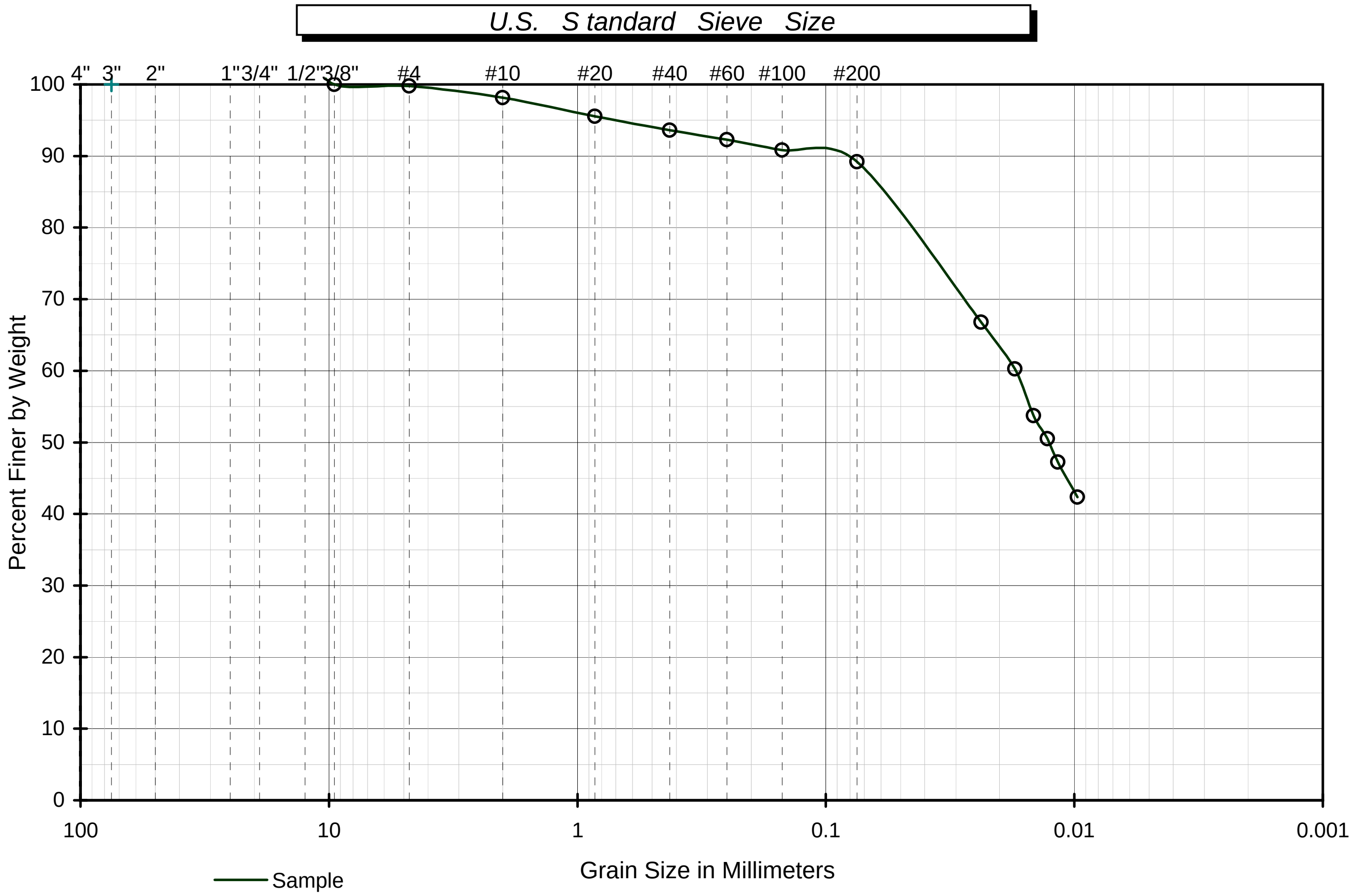
Figure B4

GRAIN SIZE DISTRIBUTION



*Unified Soil Classification**

Silt (ML)

Parameter	Grain Size (mm)**
D10	nv
D16	nv
D30	nv
D50	0.013
D60	0.017
D84	0.057

** nv - no value (insufficient data)

Cu = nv

Cc = nv

Sieve Size	Percent Passing by Weight	Hydrometer Grain Size (mm)	Hydrometer % Passing by Weight
4"		0.0237	**66.8**
3"		0.0174	**60.3**
2.5"		0.0146	**53.7**
2"		0.0128	**50.5**
1.5"		0.0117	**47.2**
1"		0.0097	**42.3**
3/4"			
1/2"			
3/8"	**100**		
#4	**100**		
#10	**98**		
#20	**96**		
#40	**94**		
#60	**92**		
#100	**91**		
#200	**89.2**		
0.02mm	**63.8**		

* - Unified soil classification in general accordance with ASTM D2487

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION

D422/D1140

Boring 05-5, Sample S-9

2005 31-1-01874-002

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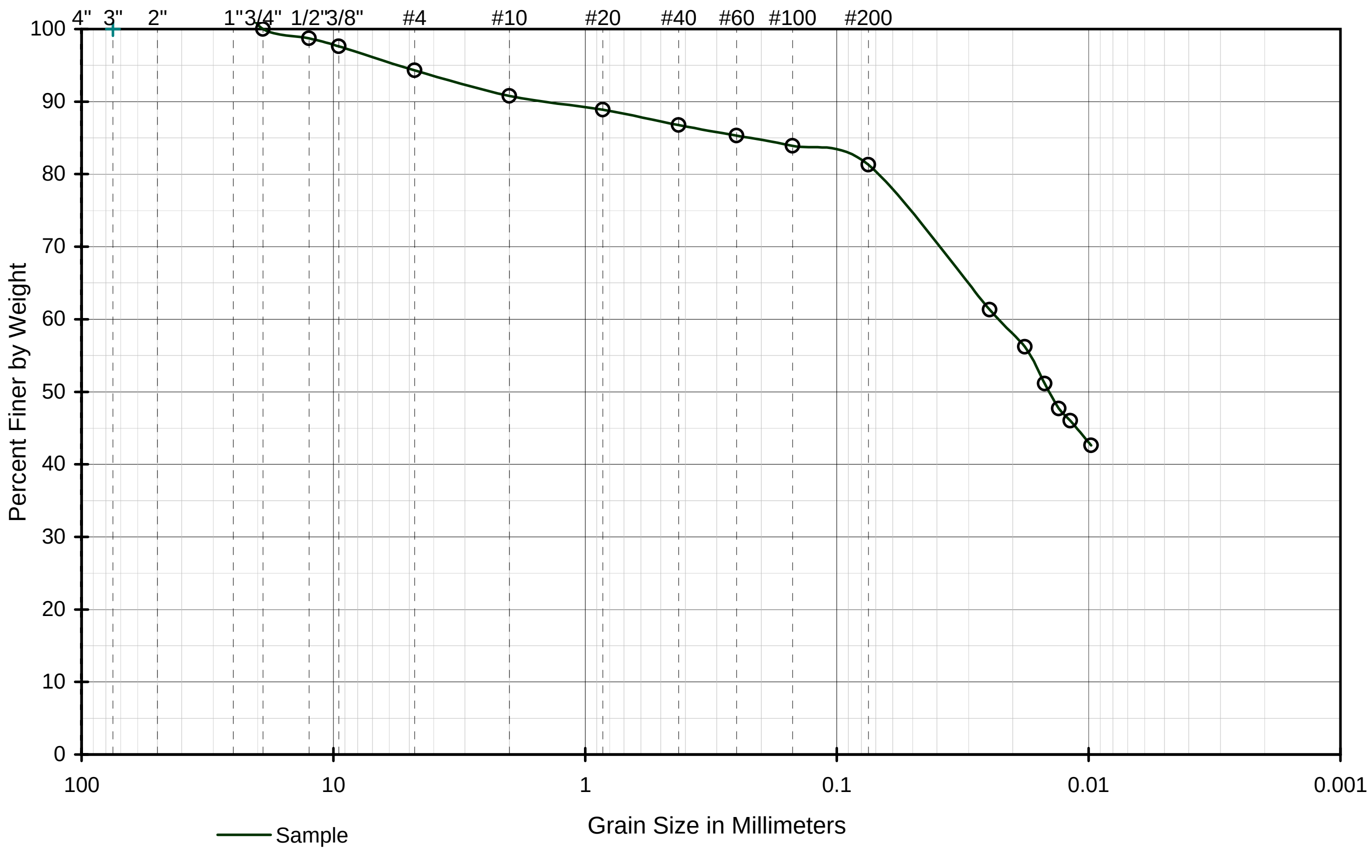
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Figure B5

GRAIN SIZE DISTRIBUTION

U.S. Standard Sieve Size



<u>*Unified Soil Classification**</u>

Silt with sand (ML)

Sieve Size	Percent Passing by Weight	Hydrometer Grain Size (mm)	Hydrometer % Passing by Weight
4"		0.0247	**61.3**
3"		0.0179	**56.2**
2.5"		0.0149	**51.1**
2"		0.0131	**47.7**
1.5"		0.0118	**46.0**
1"		0.0098	**42.6**
3/4"	**100**		
1/2"	**99**		
3/8"	**98**		
#4	**94**		
#10	**91**		
#20	**89**		
#40	**87**		
#60	**85**		
#100	**84**		
#200	**81.3**		
0.02mm	**59.6**		

Parameter	***Grain Size (mm)****
D10	nv
D16	nv
D30	nv
D50	0.014
D60	0.023
D84	0.156

** nv - no value (insufficient data)

Cu = nv
Cc = nv

* - Unified soil classification in general accordance with ASTM D2487

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION

D422/D1140

Boring 05-6, Sample S-4

2005

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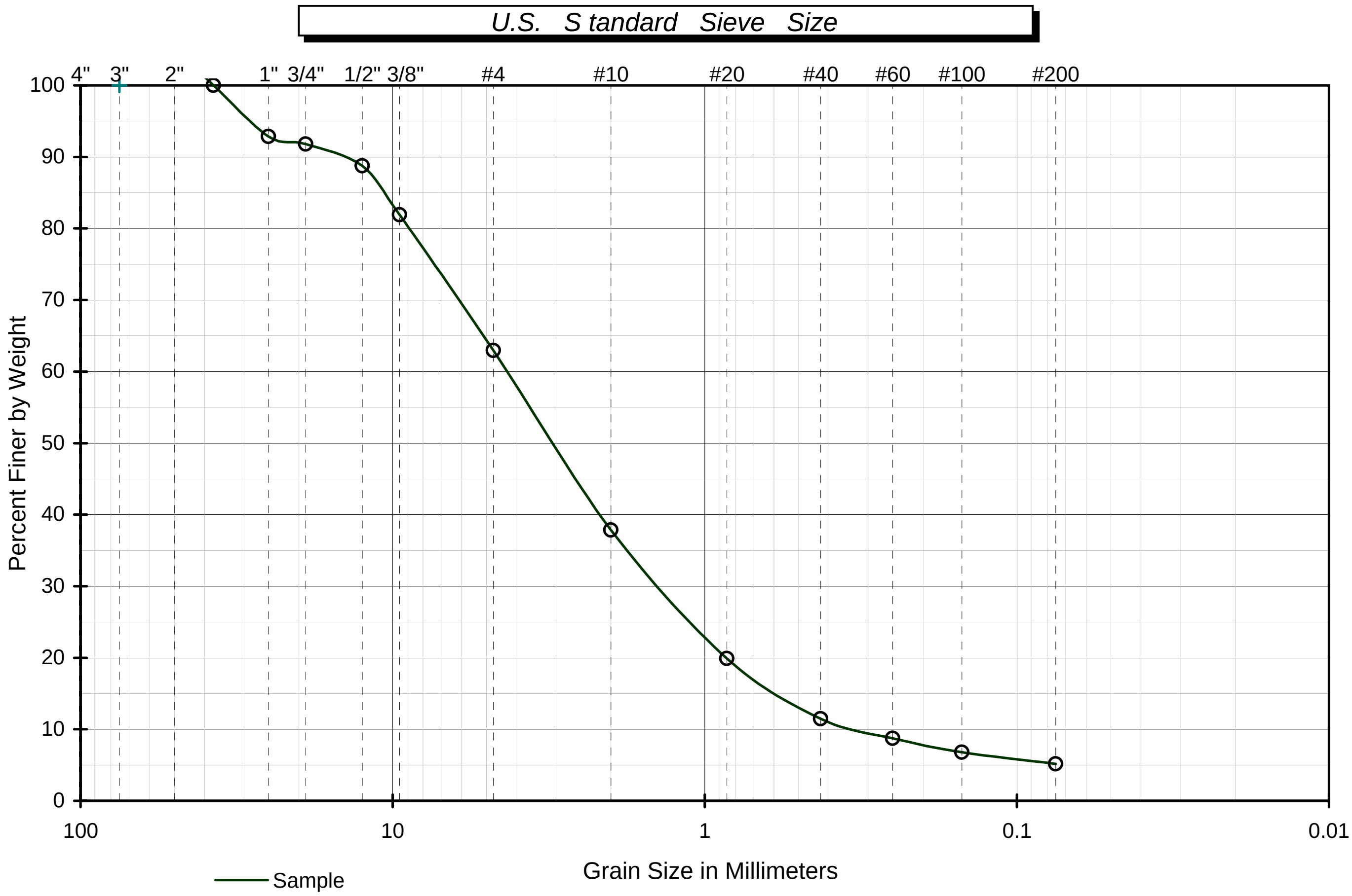
Figure B6

GRAIN SIZE DISTRIBUTION



*Unified Soil Classification**

Well graded sand with silt and gravel (SW-SM)

Parameter	Grain Size (mm)**
D10	0.320
D16	0.617
D30	1.376
D50	3.040
D60	4.293
D84	10.324

** nv - no value (insufficient data)

Cu = 13.4
Cc = 1.4

Sieve Size	Percent Passing by Weight
4"	
3"	
2.5"	
2"	
1.5"	100
1"	93
3/4"	92
1/2"	89
3/8"	82
#4	63
#10	38
#20	20
#40	11
#60	9
#100	7
#200	5.2
0.02mm	

* - Unified soil classification in general accordance with ASTM D2487

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION

C136/C117

Boring 05-6, Sample S-5

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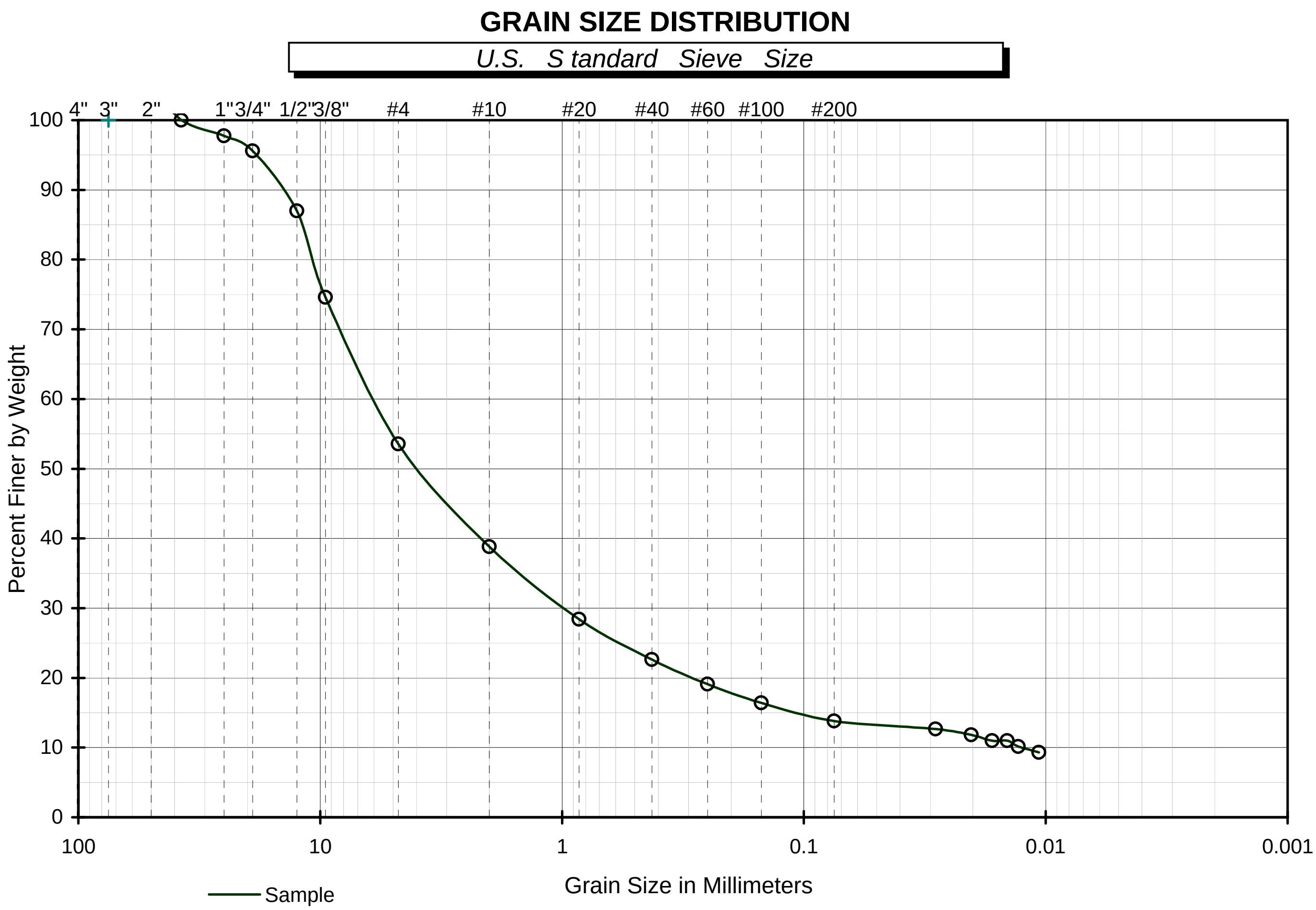
Figure B7



*Unified Soil Classification**

Silty gravel with sand (GM)

Parameter	*Grain Size (mm)***
D10	0.013
D16	0.134
D30	0.969
D50	3.858
D60	5.875
D84	11.702

** nv - no value (insufficient data)

Cu = 467.4
Cc = 12.7

Sieve Size	Percent Passing by Weight	Hydrometer Grain Size (mm)	Hydrometer % Passing by Weight
4"		0.0285	**12.7**
3"		0.0203	**11.8**
2.5"		0.0167	**11.0**
2"		0.0144	**11.0**
1.5"	**100**	0.0130	**10.1**
1"	**98**	0.0107	**9.3**
3/4"	**96**		
1/2"	**87**		
3/8"	**75**		
#4	**54**		
#10	**39**		
#20	**28**		
#40	**23**		
#60	**19**		
#100	**16**		
#200	**13.8**		
0.02mm	**11.1**		

* - Unified soil classification in general accordance with ASTM D2487

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION

D422/D1140

Boring 05-7, Sample S-2

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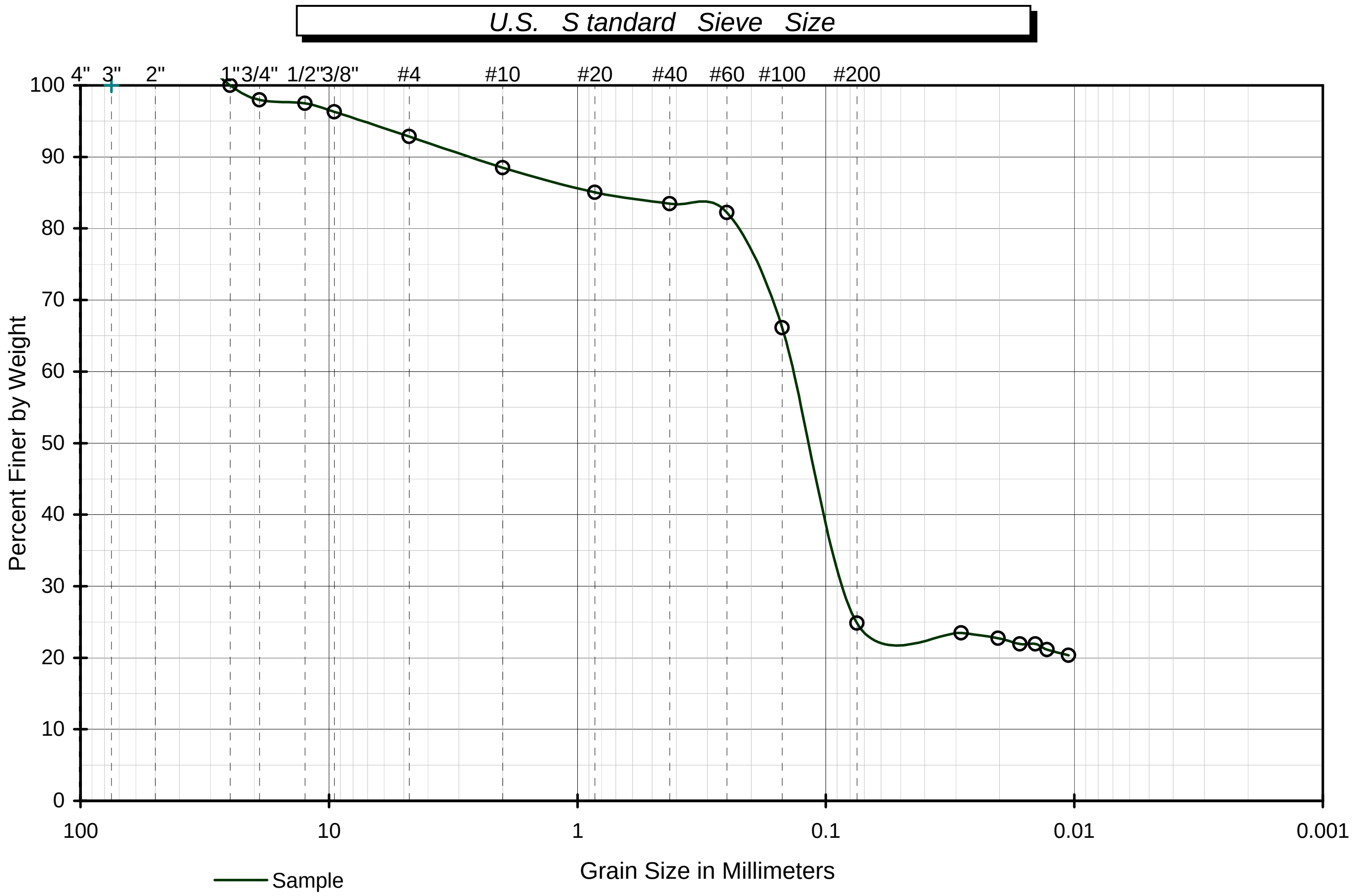
Figure B8

GRAIN SIZE DISTRIBUTION



*Unified Soil Classification**

Silty sand (SM)

Parameter	Grain Size (mm)**
D10	nv
D16	nv
D30	0.082
D50	0.114
D60	0.135
D84	0.538

** nv - no value (insufficient data)

Cu = nv
Cc = nv

Sieve Size	Percent Passing by Weight	Hydrometer Grain Size (mm)	Hydrometer % Passing by Weight
4"		0.0285	**23.5**
3"		0.0202	**22.7**
2.5"		0.0166	**21.9**
2"		0.0144	**21.9**
1.5"		0.0129	**21.1**
1"	**100**	0.0105	**20.4**
3/4"	**98**		
1/2"	**97**		
3/8"	**96**		
#4	**93**		
#10	**88**		
#20	**85**		
#40	**83**		
#60	**82**		
#100	**66**		
#200	**24.9**		
0.02mm	**22.0**		

* - Unified soil classification in general accordance with ASTM D2487

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION

D422/D1140

Boring 05-8, Sample S-2

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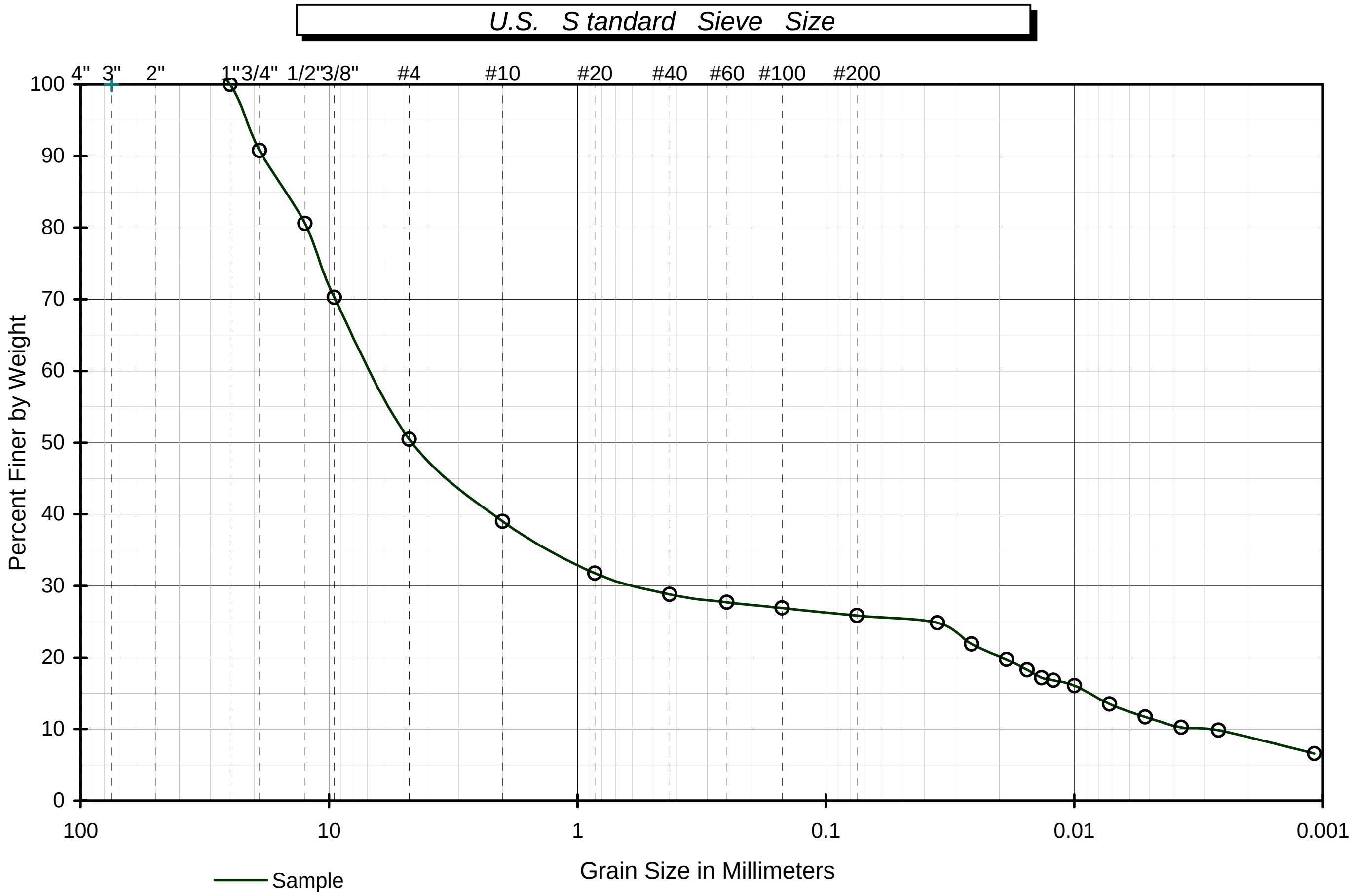
Figure B9

GRAIN SIZE DISTRIBUTION



<u>*Unified Soil Classification**</u>

Silty gravel with sand (GM)

Parameter	Grain Size (mm)**
D10	0.003
D16	0.010
D30	0.562
D50	4.583
D60	6.628
D84	14.388

** nv - no value (insufficient data)

Cu = 2197.8
Cc = 15.8

Sieve Size	Percent Passing by Weight	Hydrometer Grain Size (mm)	Hydrometer % Passing by Weight
4"		0.0355	24.8
3"		0.0259	21.9
2.5"		0.0187	19.7
2"		0.0155	18.2
1.5"		0.0135	17.2
1"	100	0.0121	16.8
3/4"	91	0.0100	16.1
1/2"	81	0.0072	13.5
3/8"	70	0.0052	11.7
#4	50	0.0037	10.2
#10	39	0.0026	9.9
#20	32	0.0011	6.6
#40	29		
#60	28		
#100	27		
#200	25.9		
0.02mm	21.4		

* - Unified soil classification in general accordance with ASTM D2487

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION

D422/D1140

Boring 05-9, Sample S-1

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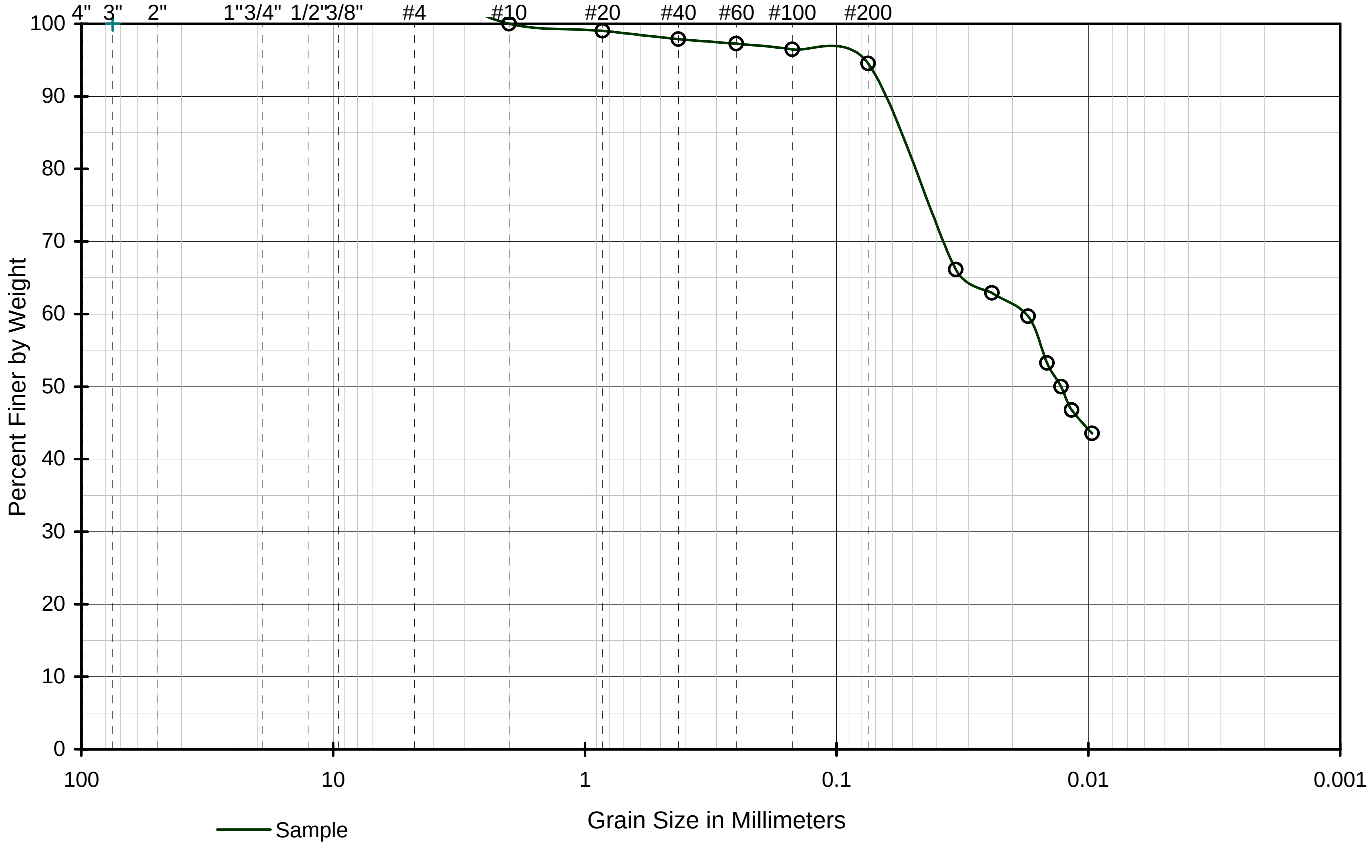
Figure B10

GRAIN SIZE DISTRIBUTION

U.S. Standard Sieve Size



<u>*Unified Soil Classification**</u>

Silt (ML)

Parameter	Grain Size (mm)**
D10	nv
D16	nv
D30	nv
D50	nv
D60	0.018
D84	0.056

** nv - no value (insufficient data)

Cu = nv
Cc = nv

Sieve Size	Percent Passing by Weight	Hydrometer Grain Size (mm)	Hydrometer % Passing by Weight
4"		0.0336	**66.1**
3"		0.0241	**62.9**
2.5"		0.0174	**59.7**
2"		0.0146	**53.2**
1.5"		0.0128	**50.0**
1"		0.0117	**46.8**
3/4"		0.0097	**43.5**
1/2"			
3/8"			
#4			
#10	**100**		
#20	**99**		
#40	**98**		
#60	**97**		
#100	**96**		
#200	**94.5**		
0.02mm	**61.5**		

* - Unified soil classification in general accordance with ASTM D2487

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Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION

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Boring 05-10, Sample S-4

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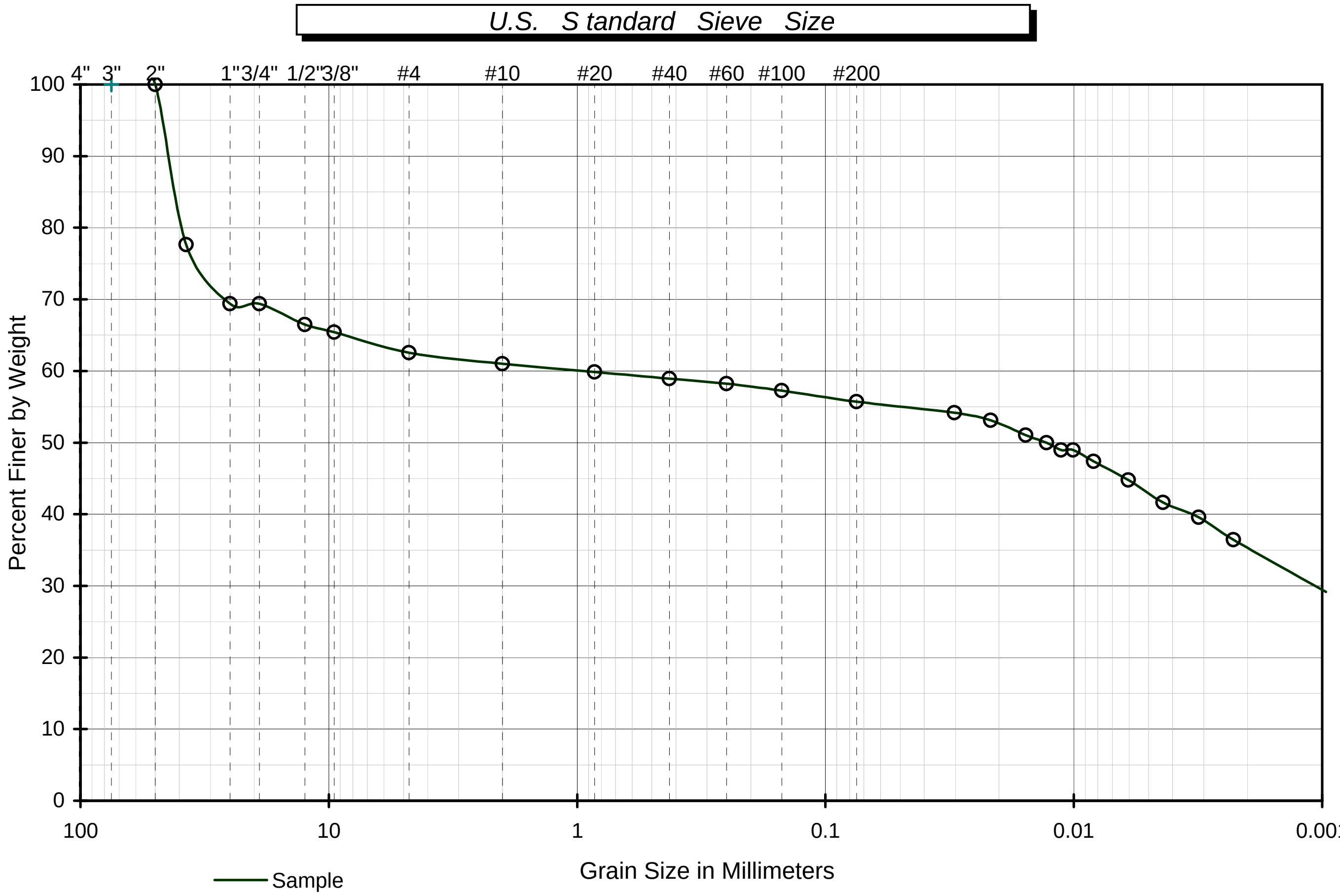
Figure B11

GRAIN SIZE DISTRIBUTION



*Unified Soil Classification**

Sandy lean clay (CL)

Parameter	Grain Size (mm)**
D10	nv
D16	nv
D30	0.001
D50	0.013
D60	0.943
D84	40.696

** nv - no value (insufficient data)

Cu = nv
Cc = nv

Sieve Size	Percent Passing by Weight	Hydrometer Grain Size (mm)	Hydrometer % Passing by Weight
4"		0.0302	54.1
3"		0.0216	53.1
2.5"		0.0156	51.0
2"	100	0.0129	50.0
1.5"	78	0.0112	48.9
1"	69	0.0101	48.9
3/4"	69	0.0083	47.4
1/2"	66	0.0060	44.8
3/8"	65	0.0044	41.7
#4	63	0.0031	39.6
#10	61	0.0023	36.4
#20	60	0.0010	29.2
#40	59		
#60	58		
#100	57		
#200	55.7		
0.02mm	51.5		

* - Unified soil classification in general accordance with ASTM D2487

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GRAIN SIZE DISTRIBUTION
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Boring 05-11, Sample S-1

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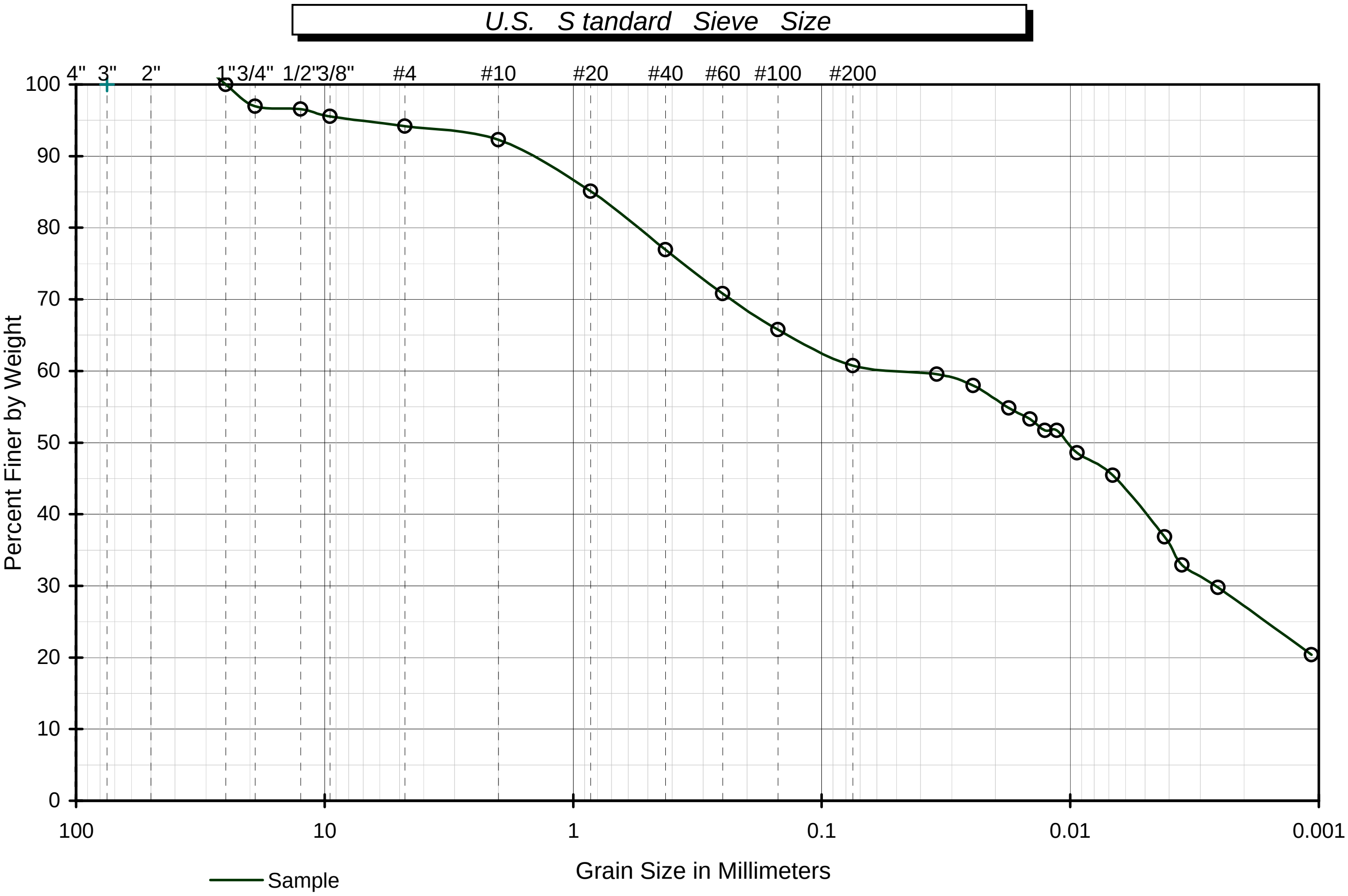
Figure B12

GRAIN SIZE DISTRIBUTION



*Unified Soil Classification**

Sandy lean clay (CL)

Parameter	Grain Size (mm)**
D10	nv
D16	nv
D30	0.003
D50	0.010
D60	0.046
D84	0.776

** nv - no value (insufficient data)

Cu = nv

Cc = nv

Sieve Size	Percent Passing by Weight	Hydrometer Grain Size (mm)	Hydrometer % Passing by Weight
4"		0.0344	**59.5**
3"		0.0245	**58.0**
2.5"		0.0176	**54.8**
2"		0.0145	**53.3**
1.5"		0.0127	**51.7**
1"	**100**	0.0113	**51.7**
3/4"	**97**	0.0094	**48.6**
1/2"	**97**	0.0067	**45.4**
3/8"	**96**	0.0042	**36.8**
#4	**94**	0.0036	**32.9**
#10	**92**	0.0025	**29.8**
#20	**85**	0.0011	**20.4**
#40	**77**		
#60	**71**		
#100	**66**		
#200	**60.7**		
0.02mm	**56.8**		

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Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION

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Boring 05-11, Sample S-2

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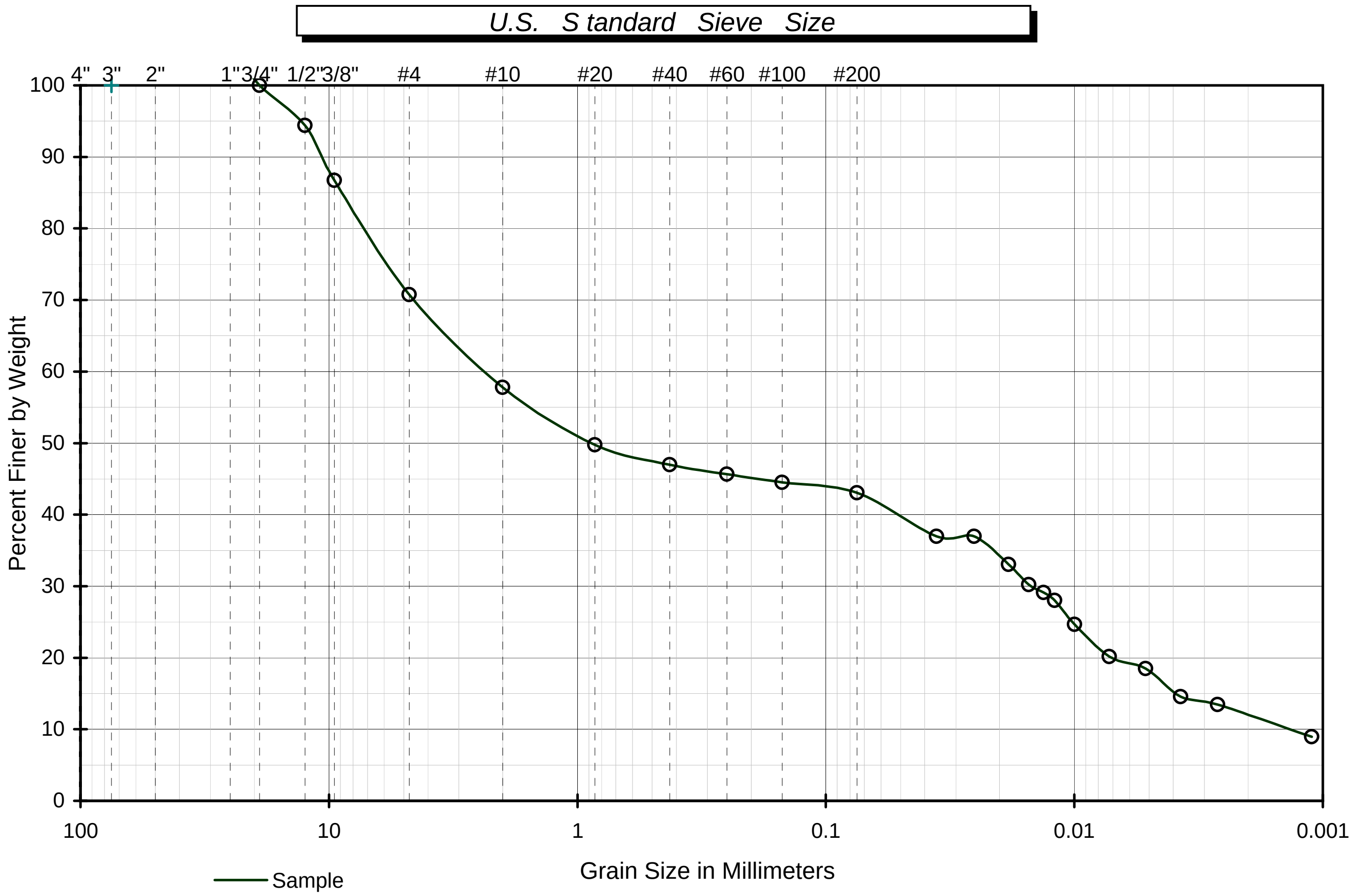
Figure B13

* - Unified soil classification in general accordance with ASTM D2487

GRAIN SIZE DISTRIBUTION



<u>*Unified Soil Classification**</u>

Silty gravel with sand (GM)

Parameter	***Grain Size (mm)****
D10	0.001
D16	0.004
D30	0.015
D50	0.871
D60	2.317
D84	8.448

** nv - no value (insufficient data)

Cu = 1706.1

Cc = 0.1

Sieve Size	Percent Passing by Weight	Hydrometer Grain Size (mm)	Hydrometer % Passing by Weight
4"		0.0358	**37.0**
3"		0.0253	**37.0**
2.5"		0.0184	**33.0**
2"		0.0153	**30.2**
1.5"		0.0133	**29.1**
1"		0.0120	**28.0**
3/4"	**100**	0.0100	**24.6**
1/2"	**94**	0.0072	**20.2**
3/8"	**87**	0.0052	**18.5**
#4	**71**	0.0037	**14.6**
#10	**58**	0.0027	**13.4**
#20	**50**	0.0011	**9.0**
#40	**47**		
#60	**46**		
#100	**45**		
#200	**43.1**		
0.02mm	**35.9**		

* - Unified soil classification in general accordance with ASTM D2487

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Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION

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Boring 05-12, Sample S-1

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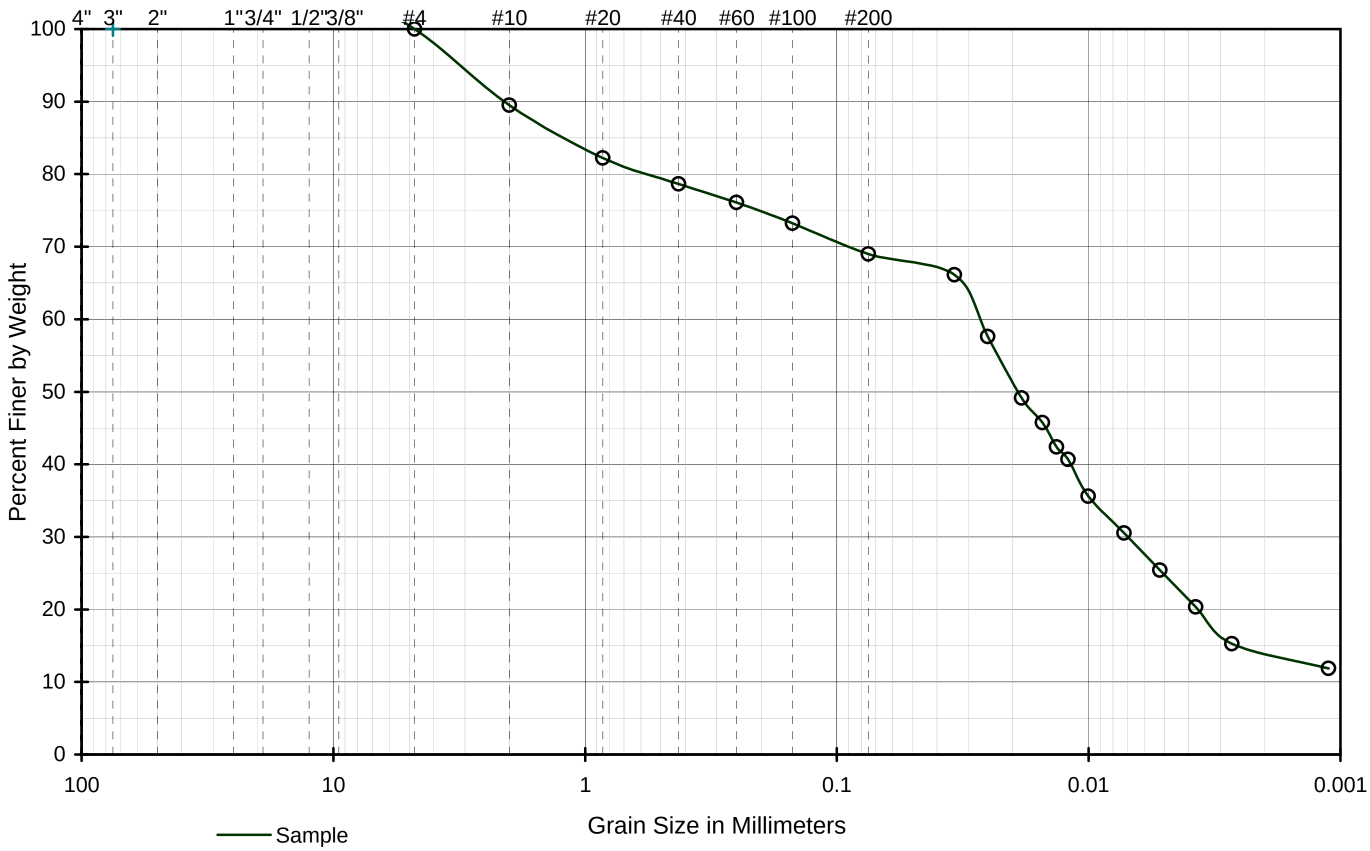
Figure B14

GRAIN SIZE DISTRIBUTION



*Unified Soil Classification**

Sandy silt (ML)

Parameter	*Grain Size (mm)***
D10	nv
D16	0.003
D30	0.007
D50	0.019
D60	0.027
D84	1.050

** nv - no value (insufficient data)

Cu = nv
Cc = nv

Sieve Size	Percent Passing by Weight	Hydrometer Grain Size (mm)	Hydrometer % Passing by Weight
4"		0.0341	**66.1**
3"		0.0251	**57.6**
2.5"		0.0184	**49.2**
2"		0.0153	**45.8**
1.5"		0.0134	**42.4**
1"		0.0121	**40.7**
3/4"		0.0100	**35.6**
1/2"		0.0072	**30.5**
3/8"		0.0052	**25.4**
#4	**100**	0.0037	**20.3**
#10	**89**	0.0027	**15.3**
#20	**82**	0.0011	**11.9**
#40	**79**		
#60	**76**		
#100	**73**		
#200	**69.0**		
0.02mm	**55.4**		

* - Unified soil classification in general accordance with ASTM D2487

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Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION

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Boring 05-13, Sample S-1

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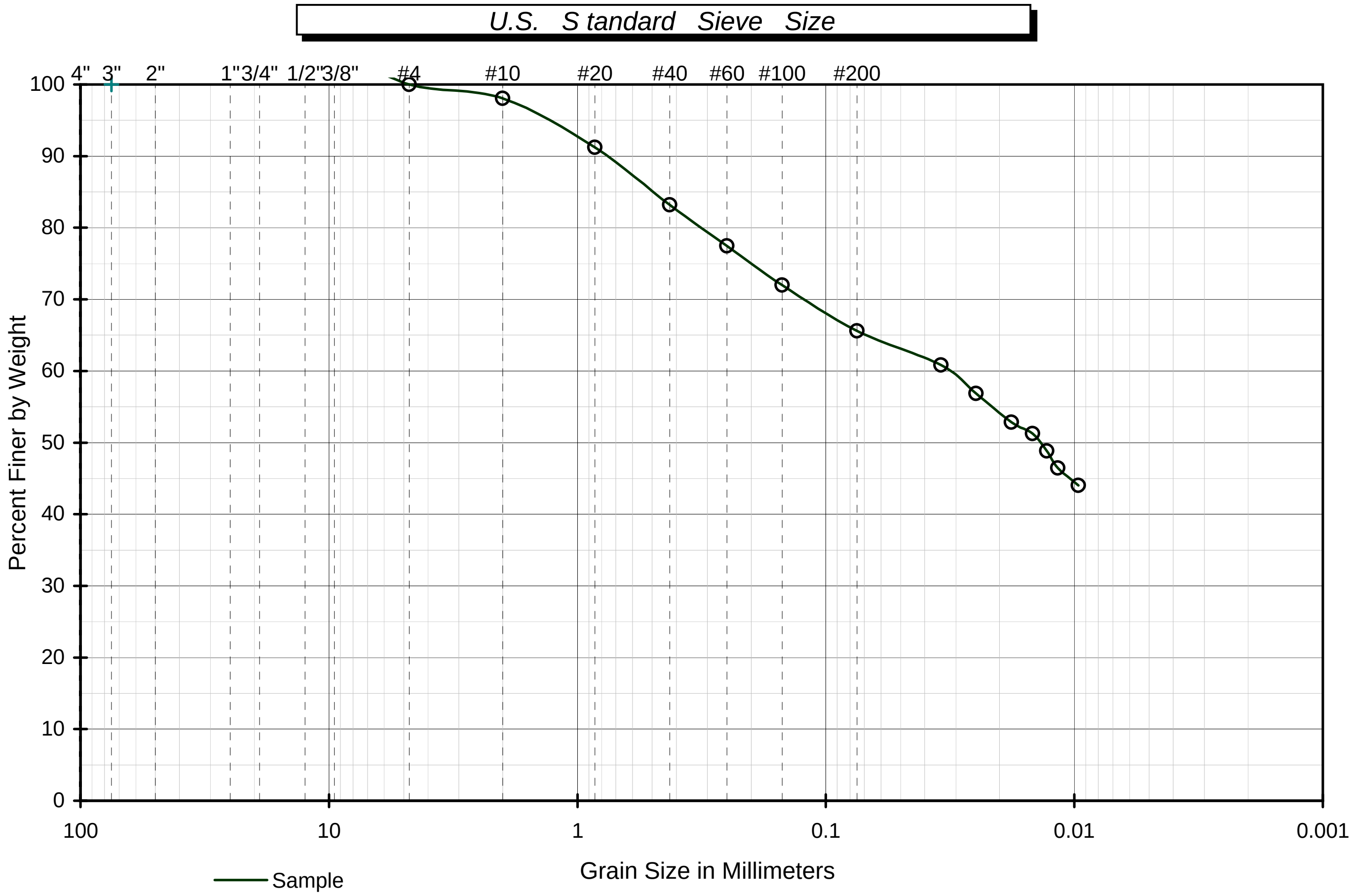
Figure B15

GRAIN SIZE DISTRIBUTION



Sieve Size	Percent Passing by Weight	Hydrometer Grain Size (mm)	Hydrometer % Passing by Weight
4"		0.0344	**60.8**
3"		0.0248	**56.8**
2.5"		0.0179	**52.8**
2"		0.0147	**51.2**
1.5"		0.0129	**48.8**
1"		0.0117	**46.4**
3/4"		0.0096	**44.0**
1/2"			
3/8"			
#4	**100**		
#10	**98**		
#20	**91**		
#40	**83**		
#60	**77**		
#100	**72**		
#200	**65.6**		
0.02mm	**55.5**		

*Unified Soil Classification**

Sandy silt (ML)

Parameter	*Grain Size (mm)***
D10	nv
D16	nv
D30	nv
D50	0.014
D60	0.032
D84	0.456

** nv - no value (insufficient data)

Cu = nv
Cc = nv

* - Unified soil classification in general accordance with ASTM D2487

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION

D422/D1140

Boring 05-14, Sample S-2

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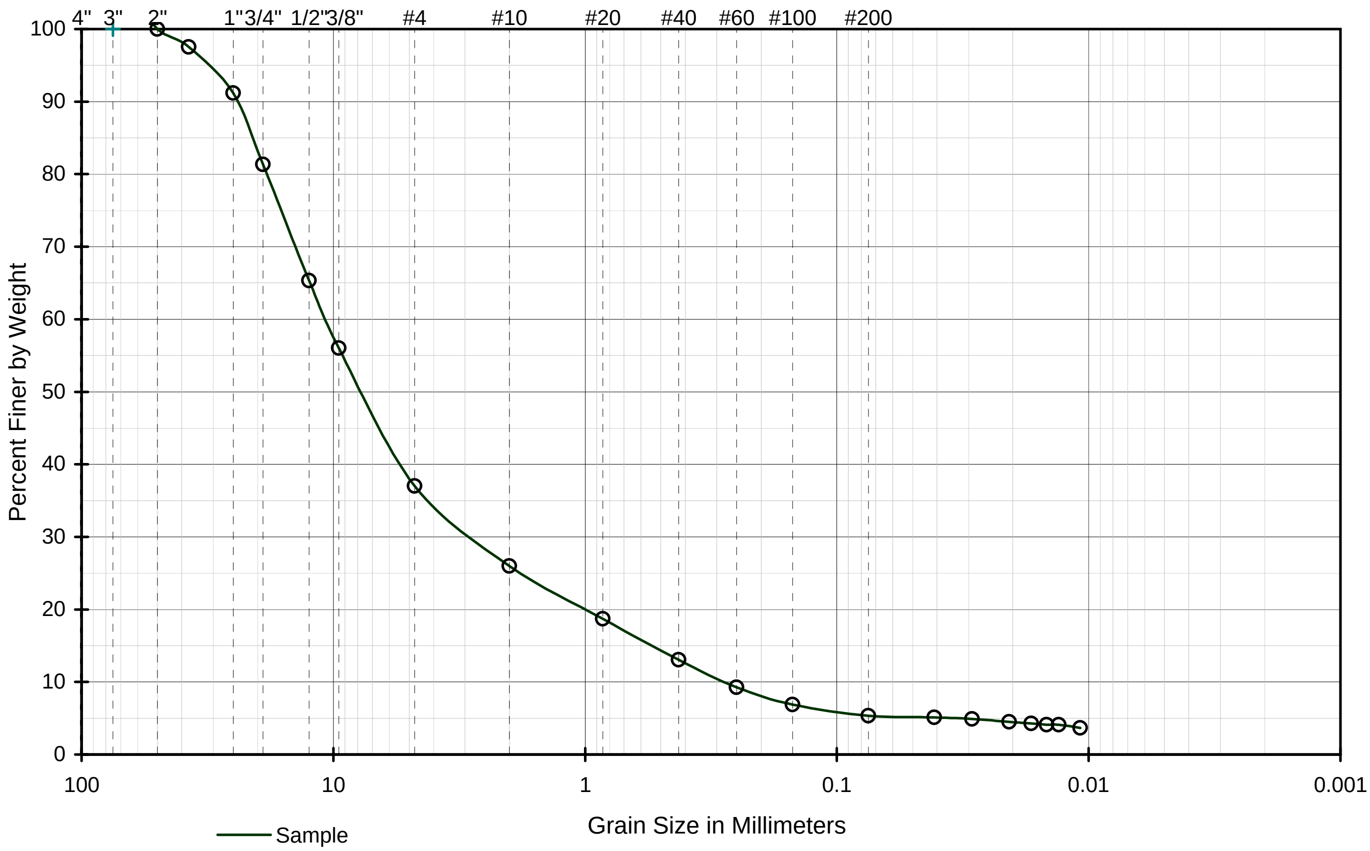
Figure B16

GRAIN SIZE DISTRIBUTION

U.S. Standard Sieve Size



*Unified Soil Classification**

Well graded gravel with silt and sand (GW-GM)

Parameter	Grain Size (mm)**
D10	0.277
D16	0.610
D30	2.738
D50	7.624
D60	10.683
D84	20.455

** nv - no value (insufficient data)

Cu = 38.6

Cc = 2.5

Sieve Size	Percent Passing by Weight	Hydrometer Grain Size (mm)	Hydrometer % Passing by Weight
4"		0.0410	5.1
3"		0.0290	4.9
2.5"		0.0207	4.5
2"	100	0.0169	4.3
1.5"	98	0.0147	4.1
1"	91	0.0131	4.1
3/4"	81	0.0108	3.7
1/2"	65		
3/8"	56		
#4	37		
#10	26		
#20	19		
#40	13		
#60	9		
#100	7		
#200	5.3		
0.02mm	4.3		

* - Unified soil classification in general accordance with ASTM D2487

Geotechnical Investigation
Potential Relocation Sites
Kivalina, Alaska

GRAIN SIZE DISTRIBUTION

D422/D1140

Test Pit TP-05-1, Sample S-1

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Figure B17

APPENDIX C

Project Photographs


Simiq. Boring 05-1.

Simiq. Boring 05-1, Sample S-1.


Simiq. Boring 05-1.

Simiq. Boring 05-1, Sample S-2.


Simiq. Boring 05-1.

Simiq. Boring 05-1, Sample S-3.

Simiq. Boring 05-1, Sample S-4.

Simiq. Boring 05-1, Sample S-5.


Simiq. Boring 05-1, Sample S-6.

Simiq. Boring 05-1, Sample S-7.

Simiq. Boring 05-1, Sample S-8.

Simiq. Boring 05-1, Sample S-9.


Simiq. Boring 05-1, Sample S-10.


Simiq. Boring 05-1, Sample S-11.


Simiq. Boring 05-1, Sample S-12.


Simiq. Boring 05-1, Sample S-13.


Simiq. Boring 05-1, Sample S-14.


Simiq. Boring 05-2, Sample S-1.

Simiq. Boring 05-2, Sample S-2.

Simiq. Boring 05-2, Sample S-4.


Simiq. Boring 05-2, Sample S-3.

Simiq. Boring 05-2, Sample S-5.

Simiq. Boring 05-2, Sample S-4.

Simiq. Boring 05-2, Sample S-6.

Simiq. Boring 05-2, Sample S-7.

Simiq. Boring 05-2, Sample S-8.

Simiq. Boring 05-2, Sample S-7.

Simiq. Boring 05-2, Sample S-9.

Simiq. Boring 05-2, Sample S-8.

Simiq. Boring 05-2, Sample S-9.

Simiq. Boring 05-2, Sample S-10.

Simiq. Boring 05-2, Sample S-12.

Simiq. Boring 05-2, Sample S-10.

Simiq. Boring 05-2, Sample S-12

Simiq. Boring 05-2, Sample S-11.

Imnakuk Bluff. Boring 05-3.

Imnakuk Bluff. Boring 05-3, Sample S-2.

Imnakuk Bluff. Boring 05-3.

Imnakuk Bluff. Boring 05-3, Sample S-3.

Imnakuk Bluff. Boring 05-3, Sample S-1.

Imnakuk Bluff. Boring 05-3, Sample S-4.

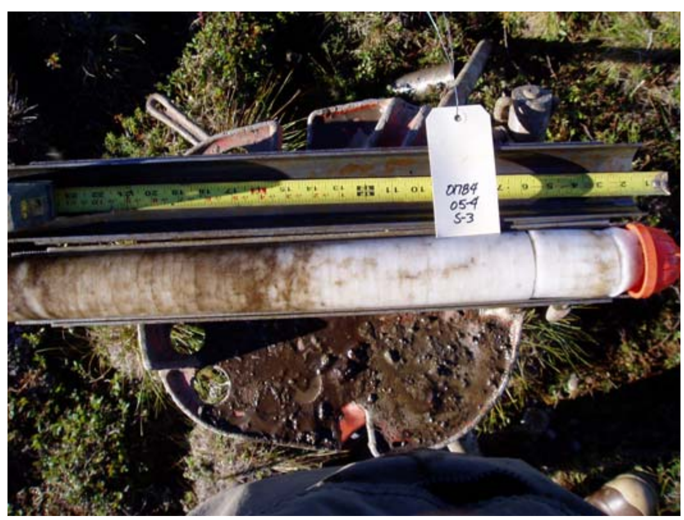
Imnakuk Bluff. Boring 05-3, Sample S-5.


Imnakuk Bluff. Boring 05-4. Seven-foot depth.


Imnakuk Bluff. Boring 05-4.

Imnakuk Bluff. Boring 05-4, Sample S-2.

Imnakuk Bluff. Boring 05-4, Sample S-1.



Imnakuk Bluff. Boring 05-4, Sample S-3.

Imnakuk Bluff. Boring 05-4, Sample S-4.

Imnakuk Bluff. Boring 05-4, Sample S-7.

Imnakuk Bluff. Boring 05-4, Sample S-5.


Imnakuk Bluff. Boring 05-5.

Imnakuk Bluff. Boring 05-4, Sample S-6.

Imnakuk Bluff. Boring 05-5, Sample S-1.

Imnakuk Bluff. Boring 05-5, Sample S-2.

Imnakuk Bluff. Boring 05-5, Sample S-5.

Imnakuk Bluff. Boring 05-5, Sample S-3.

Imnakuk Bluff. Boring 05-5, Sample S-6.

Imnakuk Bluff. Boring 05-5, Sample S-4.

Imnakuk Bluff. Boring 05-5, Sample S-7.

Imnakuk Bluff. Boring 05-5, Sample S-8.

Imnakuk Bluff. Boring 05-6, Sample S-1.

Imnakuk Bluff. Boring 05-5, Sample S-7.

Imnakuk Bluff. Boring 05-6, Sample S-2.

Imnakuk Bluff. Boring 05-6.

Imnakuk Bluff. Boring 05-6, Sample S-3.

Imnakuk Bluff. Boring 05-6, Sample S-3.

Imnakuk Bluff. Boring 05-6, Sample S-5.

Imnakuk Bluff. Boring 05-6, Sample S-4.

Imnakuk Bluff. Boring 05-6, Sample S-4.


Tatchim Isua. Overview of site.

Tatchim Isua. Boring 05-7, Sample S-2.


Tatchim Isua. Boring 05-7.

Tatchim Isua. Boring 05-7, Sample S-3.

Tatchim Isua. Boring 05-7, Sample S-1.


Tatchim Isua. Boring 05-8.

Tatchim Isua. Boring 05-8, Sample S-1.

Tatchim Isua. Boring 05-8, Sample S-3.


Tatchim Isua. Boring 05-8, Sample S-1.


Tatchim Isua. Boring 05-8, Sample S-5.

Tatchim Isua. Boring 05-8, Sample S-2.


Tatchim Isua. Boring 05-9.

Tatchim Isua. Boring 05-9, Sample S-1.

Tatchim Isua. Boring 05-9, Sample S-3.

Tatchim Isua. Boring 05-9, Sample S-1.


Tatchim Isua. Boring 05-10.

Tatchim Isua. Boring 05-9, Sample S-2.

Tatchim Isua. Boring 05-10, Sample S-1.

Tatchim Isua. Boring 05-10, Sample S-2.

Tatchim Isua. Boring 05-10, Sample S-5.

Tatchim Isua. Boring 05-10, Sample S-3.


Tatchim Isua. Boring 05-11.

Tatchim Isua. Boring 05-10, Sample S-4.

Tatchim Isua. Boring 05-11, Sample S-1.

Tatchim Isua. Boring 05-11, Sample S-2.


Tatchim Isua. Boring 05-11, Sample S-4.


Tatchim Isua. Boring 05-11, Sample S-3.


Tatchim Isua. Boring 05-12.


Tatchim Isua. Boring 05-11, Sample S-3.

Tatchim Isua. Boring 05-12, Sample S-1.

Tatchim Isua. Boring 05-12, Sample S-2.

Tatchim Isua. Boring 05-13, Sample S-1.

Tatchim Isua. Boring 05-12, Sample S-3.

Tatchim Isua. Boring 05-13, Sample S-2.


Tatchim Isua. Boring 05-13.

Tatchim Isua. Boring 05-13, Sample S-3.


Tatchim Isua. Boring 05-13, Sample S-4.


Tatchim Isua. Boring 05-14, Sample S-1.


Tatchim Isua. Boring 05-13, Sample S-5.


Tatchim Isua. Boring 05-14, Sample S-2.


Tatchim Isua. Boring 05-14.


Tatchim Isua. Boring 05-14, Sample S-3.

Tatchim Isua. Boring 05-14, Sample S-4.

APPENDIX D

Shannon & Wilson Soil and Rock Description System

Soil and Rock Classification

Soil samples were classified in accordance with Shannon & Wilson's soil classification system. This system is generally based on the Unified Soil Classification System (USCS) presented in ASTM D 2487 *Classification of Soils for Engineering Purposes (Unified Soil Classification System).* The soil classification system provides for the identification of the following characteristics in the order that they are listed.

a) Relative density or consistency – The relative consistency or density of the material is estimated based on the penetration resistance of unfrozen soil. The relative consistency is used to describe fine-grained cohesive soils (such as clay) and the relative density is used to define coarse-grained granular soils (such as sand). The penetration resistance is calculated by summing the blows required to drive the split-spoon sampler the final 12 inches of an 18-inch sample run. The penetration resistance is not valid in frozen soils. Relative density or consistency is determined according to the following table.

Penetration Resistance (blows per foot)	**Relative Consistency**	**Penetration Resistance (blows per foot)**	**Relative Density**
< 2	Very Soft	0 – 4	Very Loose
2 – 4	Soft	4 – 10	Loose
4 – 8	Medium Stiff	10 – 30	Medium Dense
8 – 15	Stiff	30 – 50	Dense
15 – 30	Very Stiff	> 50	Very Dense
> 30	Hard		

b) Color – Color descriptions are generally kept as simple as practical, using basic soil colors such as brown, gray, and tan. Color is generally used to distinguish soil layers or indicate the degree of weathering within a single soil layer.

c) Minor Constituents, Major Constituents, and Trace Constituents – In the field, visual-manual procedures are used to classify the soil type. The constituents are generally limited to (in decreasing size) boulders, cobbles, gravel, sand, silt, and clay. Minor constituents are soil types that comprise a significant portion of the sample (more than 5 percent), but are not the largest component of the sample. Minor constituents that comprise between 5 and 12 percent of the sample are identified as "slightly."

The major constituent is the one that comprises the largest fraction of the soil mass. The major constituent will generally appear in the form of all capital letters, such as SILT.

Trace constituents are soil types that are observed in the soil sample but comprise a limited portion of the sample. The presence of these soil types may or may not influence the behavior of the soil.

Organics may also be considered as constituents in the soil description. The following terms are used to describe the organic content.

Descriptor	**Percent by Volume**
Occasional	0 – 1
Scattered	1 – 10
Numerous	10 – 30
Organic	Minor constituent
PEAT	Major constituent

d) Moisture content – The relative moisture content (dry, slightly moist, moist, or wet) is given to the sample based on observations of the sample. This is a qualitative description that assists the engineer in identifying how the sample may behave at that particular moisture content.

e) Other – following the relative moisture content, the geologist or engineer may also include additional observations that will describe the characteristics or behavior of the soil. These terms include structure, plasticity, gradation, grain shape, cementation, description of organics, or dilatancy. Some of these descriptions are presented in the following tables.

Structure

Descriptor	Criteria, Thickness
Parting	0 – 1/16 inch
Seam	1/16 – ½ inch
Layer	> ½ inch
Lamination	< ¼ inch
Pocket	Irregular, < 1 foot
Varved	Alternating seams or laminations
Occasional	< 1 per foot
Frequent	>= 1 per foot
Stratified	Alternating layers
Interbedded	Alternating layers > ½ inch thick
Laminated	Alternating layers < ¼ inch thick
Fractured	Breaks easily along definite fractured planes
Slickensided	Polished, glossy, striated fractured planes
Blocky, Diced	Easily breaks into small angular lumps
Homogeneous	Same color and appearance throughout
Sheared	Disturbed texture, mix of strengths

Plasticity

Descriptor	Criteria, Thickness
Nonplastic	A 1/8-inch thread cannot be rolled at any water content
Low	The thread can be rolled and the lump cannot be formed when drier than the plastic limit
Medium	The thread is easy to roll and not much time is required to reach the plastic limit. The thread cannot be rerolled after reaching the plastic limit. The lump crumbles when drier than the plastic limit.
High	It takes considerable time rolling and kneading to reach the plastic limit. The thread can be rerolled several times after reaching the plastic limit. The lump can be formed without crumbling when drier than the plastic limit.

Shannon & Wilson's frozen soil classification is based on the descriptions developed by Linell and Kaplar (1966). The frozen soil descriptions are primarily based on visual observations regarding the presence, orientation, and form of ice. A summary of the Linnel and Kaplar classification is presented on the following page.

Description			Designation
Segregated ice is not visible by eye	Friable, poorly bonded Material is easily broken up		Nf
	Well bonded – Soil particles strongly held together by ice	No excess ice	Nbn
		Excess ice	Nbe
Segregated ice is visible by eye (less than 1-inch thick)	Individual ice crystals or inclusions		Vx
	Ice coatings on soil particles		Vc
	Stratified or distinctly oriented ice formations		Vs
	Randomly or irregularly oriented ice formations		Vr
Ice greater than 1-inch thick	Ice with soil inclusions		ICE + soil type
	Ice without soil inclusions		ICE

(Based on Linell, K.A. and C.W. Kaplar, 1966, *Description and Classification of Frozen Soils*, U.S. Army Cold Regions Research Engineering Laboratory, Technical Report 150, Hanover, N.H.)

In addition to describing the presence, orientation and form of ice, our soil classification may also include a visual volumetric estimation of ice content and a description of the size and orientation of individual ice features.

Rock Classification

Rock samples were classified in accordance with Shannon & Wilson's rock classification system. This system incorporates that basic rock type and supplements the information with terms describing jointing or fracturing, weathering, structure, and other terms which will supplement the engineer's or geologist's understanding as to how the rock may behave.

The rock classification system provides for the identification of the following characteristics in the order that they are listed.

1) Rock Name – The rock name is the general geological term of the rock type. The rock is classified as to the general rock type (sedimentary, metamorphic, igneous, or pyroclastic), the major and minor constituents, and the rock texture.

2) Strength – A qualitative estimate of the strength of the rock is made. The terms and basis for the description of the rock strength is presented in the following table.

Descriptor	Description
Very Low	Crumbles with firm blow; peeled with knife
Low	Dents with firm blow; peeled with difficulty
Moderate	Fractures with one blow; can't be peeled
Medium High	More than one blow required to fracture
High	Many blows required to fracture
Very High	Can only be chipped with hammer

3) Basic Rock Description – The basic rock description includes general terms such as color and texture (phaneritic versus aphanitic, coarse, fine, porous, etc.) and whether a sedimentary rock is weakly or strongly cemented, and whether induration of the rock is high or slight.

4) Structure – The general structure of the rock is presented. This encompasses several observations as to the features of the rock, including a description of the fabric, the vesicularity, and any discontinuities that may be observed in the rock. The following tables present a summary of terms that may be used to describe the rock structure.

Fabric Terms

Descriptor	Description
Sedimentary Rocks	
Massive	Rock without significant structure
Bedded	Parallel arrangement from sedimentation
Fissile	Tendency to break along laminations
Metamorphic Rocks	
Foliated	Parallel arrangement or distribution of minerals
Schistose	Parallel arrangement of tabular minerals giving planar fissility
Gneissose	Segregation of minerals into bands
Cleavage	Tendency to split along secondary, planer textures or structures

Vesicularity – This term refers to small cavities in an aphanitic igneous rock formed by the expansion of a gas bubble during solidification of the rock.

Descriptor	Description
Slightly vesicular	1 to 10 percent
Moderately vesicular	10 to 30 percent
Highly vesicular	30 to 50 percent
Scorlaceous	Greater than 50 percent

Discontinuity and Stratification Spacing

Stratification Term	Discontinuity Term	Spacing
Very thick	Very wide	> 6 feet
Thick	Wide	2 to 6 feet
Medium	Medium	8 to 24 inches
Thin	Close	2-1/2 to 8 inches
Very Thin	Very Close	¾ to 2-1/2 inches
Laminated:	Extremely Close	
Thickly		¼ to ¾ inches
Thinly		< ¼ inches

Joint Roughness

Small Scale	Intermediate Scale
Rough	Stepped
Smooth	Undulating
Slickensided	Planer

5) Weathering – Weathering in the rock sample is estimated by observing potential discoloration, fracture conditions, and overall material condition.

Descriptive Term	Discoloration Extent	Fracture Condition	Material Condition
Fresh	None	Slight discoloration	Unchanged
Slightly weathered	Slight penetration away from fracture	Discolored, may contain thick filling	Partial discoloration
Moderately weathered	Significant penetration	Discolored, may contain thick filling	Partial to complete discoloration, not friable except poorly cemented rocks
Highly weathered	Throughout	—	Friable and possibly pitted, partial separation of grain boundaries, corestones may be present
Completely weathered	Throughout	—	All material changed to soil; texture and structure largely preserved

6) Additional observations of interest.

APPENDIX E

Statement of Work

STATEMENT OF WORK

CONTRACT NO. 00

DELIVERY ORDER NO 0 MOD 0

GEOTECHNICAL INVESTIGATION POTENTIAL RELOCATION SITES

KIVALINA, ALASKA

January 2005

1.0 GENERAL

The U.S. Army Corps of Engineers – Alaska District (USACE-AD) is conducting a geotechnical exploration to provide subsurface information for evaluation of potential relocation sites for the community of Kivalina, Alaska. This exploration is intended to provide geotechnical information for preliminary evaluation of the development of each of the three potential relocation sites. Other possible relocation sites where subsurface information already exists are also being evaluated. The work will include drilling and sampling of the subsurface soils and laboratory testing of selected samples. The intent of this Statement of Work is to provide the USACE-AD with sufficient flexibility to allow the addition or deletion of borings based on the findings in the field. Fieldwork activities at Kivalina shall be coordinated with the Corps; POC will be Greg Carpenter at 753-2684 or Chuck Wilson at 753-2687. This project is English Units.

1.1 Location of Work

The sites to be investigated are within the Kivalina area. The sites requiring explorations are:

a. Simiq
b. Imnakuk Bluff
c. Tatchim Isua

These sites are located 3.5 to 8.5 miles from the village of Kivalina. It is anticipated that the drilling operation will require a helicopter for transport of the drilling equipment and crew.

1.2 Work Included

The work included for this project includes the mobilization of equipment and personnel to Kivalina and to the drilling locations and all work associated with the drilling, logging and sampling of the borings. The borings will include the following for each site. The physical location of each boring will be selected by the Contractor and submitted in the Work Plan.

Simiq—One boring will be drilled to a depth of 40 feet. If the findings warrant, up to two optional borings to a depth of 40 feet may be authorized.

Imnakuk Bluff—Four borings to a depth of 25 feet or to bedrock will be drilled. Up to two optional borings to a depth of 25 feet may be authorized.

Tatchim Isua—Four borings to a depth of 25 feet or to bedrock will be drilled. Up to two optional borings to a depth of 25 feet may be authorized.

The optional borings will not be drilled without prior authorization by the USACE-AD.

The work to be performed by the Contractor includes, but is not limited to the tasks described in the following:

1. Preparing daily logs of all operations, observations, and measurements, and compiling these logs into the specified field report.
2. Providing coordination and scheduling with USACE-AD.
3. Providing supervision of drilling and soil sampling, backfilling and plugging of borings, moving between borings, and for cleaning the work areas.
4. Providing preservation and transportation of soil samples, measurement of ground water levels if encountered, and preparation of soil logs.
5. Providing all supervision, labor, materials, tools, equipment, and transportation necessary to perform laboratory testing of soils.
6. Preparing preliminary and final reports presenting the results of drilling, sampling and lab testing. The reports are also to include field methodology and operations, data interpretation, and engineering analyses and recommendations.
7. Providing all drilling and helicopter services.
8. Providing hand held GPS unit to record the horizontal location of each of the borings.

2.0 DETAILED STATEMENT OF WORK

2.1 Task 1: Work Plan

Before the starting of work, the Contractor shall prepare and submit to USACE-AD a Draft Work Plan. An electronic copy of an example Work Plan will be supplied to the Contractor for use in preparing the plan. This plan shall describe in detail the Contractor's schedule for completing the work. The Work Plan shall include the Safety, QC, and Drilling Plans. The Work Plan shall describe the operational procedures, the equipment to be used in the work including drilling equipment, calibration/standardization procedures for each piece of equipment, proposed access trails and other pertinent information relating to the planning and executing of the fieldwork. The plan must be reviewed by the USACE-AD prior to the start of work. Any deviations from the Work Plan during execution of the work shall be noted in the daily logs and reports.

2.2 Task 2: Geotechnical Investigation

2.2.1 Subtask 2a: Sampling and Logging Test Borings

2.2.1.1 General

Drilling, sampling, and testing are required to attain the investigation objectives. These objectives are to determine to the extent possible with the level of effort specified:

- The physical and mechanical properties of the soil and rock.
- The depth to the water table (if present within depth of investigation).
- The presence and character of permafrost if present.

Test boring locations will be obtained in the field with a hand held GPS unit.

Borings shall be made to determine subsurface conditions and to obtain and preserve disturbed and relatively undisturbed soil samples. Sampling and borehole logging shall be accomplished by an experienced, competent geologist, geotechnical engineer, or engineering technician. These individuals and their qualifications shall be identified in the required Work Plan.

2.2.1.2 Drilling Modifications

The Contractor shall coordinate with the USACE-AD on a daily basis to enable the Corps personnel to make decisions regarding the authorization of drilling optional borings at each of the sites. Optional borings will not be drilled without prior authorization by the USACE-AD.

2.2.1.3 Sampling in Soil

Samples shall be obtained at 2.5 feet, five feet and at intervals of five feet thereafter or at a change in material. Samples shall generally be obtained using split-barrel sampling in accordance with ASTM D 1586, Penetration Test and Split Barrel Sampling of Soils. In coarse-grain materials where insufficient penetration and material recovery is obtained using the equipment required by the ASTM, a 2 ½-inch I.D. heavy-wall split-barrel drive sampler shall be used. This modified penetration test shall be performed by driving the sampler by the impact of a 340-pound hammer falling approximately 30 inches. Otherwise, all the provisions of ASTM 1586 shall apply. Grab samples shall be procured at the surface.

Sample Handling- Split-Barrel Sampling

1. Open the split-barrel sampler.
2. Any required chemical sample shall be collected immediately after the split-barrel is opened.
3. Measure and record the length of sample recovered and the percent recovery.
4. In permafrost soils, carefully examine the sample for ice content,

especially any layers or lenses of excessive visible ice. Measure and/or estimate ranges of thickness of all ice layers, lenses, and inclusions.

5. Classify the sample according to the ASTM 2488, Description and Identification of Soils, (Visual-Manual Procedures). If the sample is frozen, classify it in accordance with ASTM D 4083, Description of Frozen Soils.
6. If ice is detected, photograph the sample. Include in the photograph a sign identifying the borehole number, sample number, depth and date of sampling. Also, photograph samples representative of differing soil types.
7. Extract the sample and place it in an airtight container. Frozen samples shall be maintained in a frozen state during storage and transport to avoid the loss of moisture.
8. The sample container shall be properly identified with the boring number and sample number and sample interval.

2.2.1.4 Backfilling Borings

The borings shall be backfilled with all remaining cuttings removed from the borings. Requests to use an alternative method and the procedure for such method shall be submitted by the Contractor for approval.

2.2.1.5 Cleanup

The work areas shall be kept in neat and orderly condition at all times. On completion of work, the material removed from the holes and not used as backfill shall be spread around the boring. The Contractor shall supervise the drill crew to leave the area in a clean condition with all equipment and trash removed to the satisfaction of USACE-AD. Any Investigative Derived Waste (IDW) shall be containerized and disposed of properly.

<u>2.2.2 Subtask 2b: Laboratory Testing</u>

2.2.2.1 General

All testing shall be completed in Corps of Engineers approved laboratories. The Contractor shall select samples representative of the soil types encountered during drilling for testing. The Contractor also shall be responsible for transporting the samples to the laboratories.

2.2.2.2 Geotechnical Test Procedures and Quantities

Test methods shall correspond to the latest addition of the referenced standard and as modified herein. All tests shall be performed on samples selected by the Contractor.

1. ASTM D 422 - Particle-Size Analysis of Soils.
2. ASTM D 2487 - Classification of Soils for Engineering Purposes.

3. ASTM D 2216 - Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock and Soil-Aggregate.

2.2.3 Subtask 2c: Reports

2.2.3.1 Field Logs

The Contractor shall keep, and furnish to USACE-AD with the final report, copies of an accurate log of each drill hole. The logs shall show the boring number, the date the boring began and finished, air temperature and weather conditions on each day of drilling, boring coordinates or other location identification, total depth, tools utilized in the drilling and sampling process, description of the material in the boring, depth at which each change in material occurs, depth at which samples were obtained and the type of sample in each instance, penetration resistance, percentage of sample recovery, depth to water table. In addition, any other data pertinent to the identification of material or to the strength or consistency of the materials in undisturbed formations shall be recorded. The Contractor shall brief and furnish field logs to USACE-AD on a daily basis.

2.2.3.2 Daily Logs

The Contractor shall keep continuous logs of all operations, observations, and measurements. These logs will be made available to the USACE-AD on a day-to-day basis if requested. These logs are to be readily available should the need arise to reinvestigate certain areas within the scope of the project. These detailed logs shall contain at least the items listed below.

The following gives the minimum requirements for the contents of the daily log:

1. Names and affiliations of personnel engaged in the work
2. Weather conditions
3. All events affecting data acquisition or quality
4. Equipment used
5. Equipment adjustments, malfunctions, and downtime with explanations
6. Dates and times of mobilization and demobilization
7. All written and verbal instructions issued by USACE-AD and a description of the resolution of any issues
8. All other relevant information and occurrences, including a general narrative of the total activity

2.2.3.3 Final Report

The Final Geotechnical Report shall present these minimum requirements:

1. Purpose and scope of investigation including site location descriptions.
2. Description of drilling, sampling and testing equipment, and methods used including horizontal and vertical control.
3. Description of pertinent regional and site geology.
4. Site surface descriptions.
5. Subsurface descriptions based upon interpretation of the test borings, and the laboratory testing and other observations on site during the course of the fieldwork.
6. Maps and figures as necessary to support the interpretations and recommendations including as appropriate: location and vicinity maps, boring location maps, data contour maps, isopachs of identified strata, and interpretive plans and cross sections.
7. Final boring logs: The boring logs shall be at a scale not smaller than 1:60 and shall contain the following information:
   a. Temporary I. D. (assigned by A/E)
   b. Permanent I. D. (assigned by USACE-AD after completion)
   c. Coordinates and elevation
   d. Names of individuals and firms performing drilling and logging
   e. Type, make and model of drill rig
   f. Size and type of casing and tools
   g. Water table depth(s)
   h. Sampling interval
   i. Lab classification- ASTM D 2487
   j. Field classification (where not lab tested)- ASTM D 2488
   k. Frozen soil description-ASTM D 4083
   l. Frost susceptibility- TM 5-822-5
   m. Sample drive hammer weight
   n. Sampling device description
   o. Blow count per 6-inch interval
   p. Date of boring
8. Laboratory test reports.
9. Analysis and Recommendations: The report shall include analysis and recommendations for the geotechnical design parameters for structures, unpaved traffic areas, and utilities.
10. This scope of work shall be included as an appendix.

3.0 SAFETY

The Contractor is responsible for the safety of his personnel, equipment, materials, and the public at all times. Drill holes shall not be left open overnight. A specific safety and accident plan in accordance with EM 385-1-1 will be included in the Work Plan.

4.0 QUALITY CONTROL

Quality Control Plan (QCP): The Contractor shall propose a system to manage, control, and document the performance of these tasks. The QC activities shall be documented and included in the final report. The Contractor shall ensure that the corporate quality policy is understood, implemented, and maintained at all levels in the organization. The Contractor shall perform continuous tracking, checks, representations, adjustments and visualization of his field data for quality control and to establish efficient field procedures. Contractor is responsible for ensuring that project work proceeds smoothly in accordance with the SOW and maintaining a continual vigilance for ways to increase efficiency and quality, as well as providing weekly summaries of Quality Control activities.

5.0 SITE INVESTIGATION AND REPRESENTATION:

The Contractor assumes responsibility for all investigations as to; the nature and location of the work, the general and local conditions (particularly those bearing upon transportation and the availability of roads and airports), the uncertainties of weather, topography and conditions of the ground, the character of equipment and facilities needed prior to and during prosecution of the work, and all other matters upon which information is reasonably obtainable and which can in any way effect the work or the cost thereof under this modification. Any failure by the Contractor to acquaint himself with all the available information will not relieve him from responsibility for estimating properly the difficulty or cost of successfully performing the work.

6.0 AVAILABILITY OF MATERIALS:

All field notes, sketches, recordings and computations made by the Contractor in completing this work shall be available at all times during the progress of the work for examination by the Contracting Officer, or his authorized representative. All such material shall become the property of the Government upon completion of the delivery order.

7.0 SCHEDULE:

The required Work Plan shall be submitted to the Government within one week of notice to proceed. The fieldwork shall be performed during April 2005. A complete set of the field logs shall be presented to the Government three days after completion of the fieldwork and a complete set of final logs 30 days thereafter. A draft report shall be submitted not later than 30 days after exploration completion. The Government then expects to use five working days for review and comment. A final report shall be submitted seven working days after review and comments are complete.

8.0 DELIVERABLES:

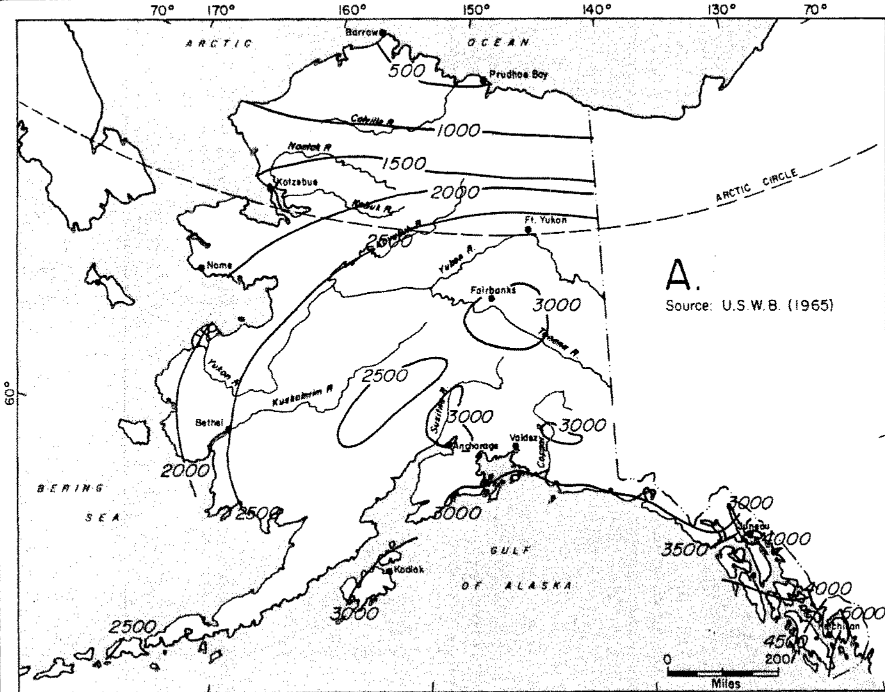
Four draft and 12 final Project Geotechnical Report copies (one unbound) shall be delivered to

U.S. ARMY ENGINEERS, ALASKA DISTRICT
CENPA-EN-ES-SG
ATTN: CHUCK WILSON
P.O. BOX 6898
ELMENDORF AFB, ALASKA 99506-6898

and shall be accompanied by a letter or shipping form listing the materials being transmitted. In addition to the hard copies, the Contractor shall provide one electronic copy of the final report in PDF format on a compact disc.

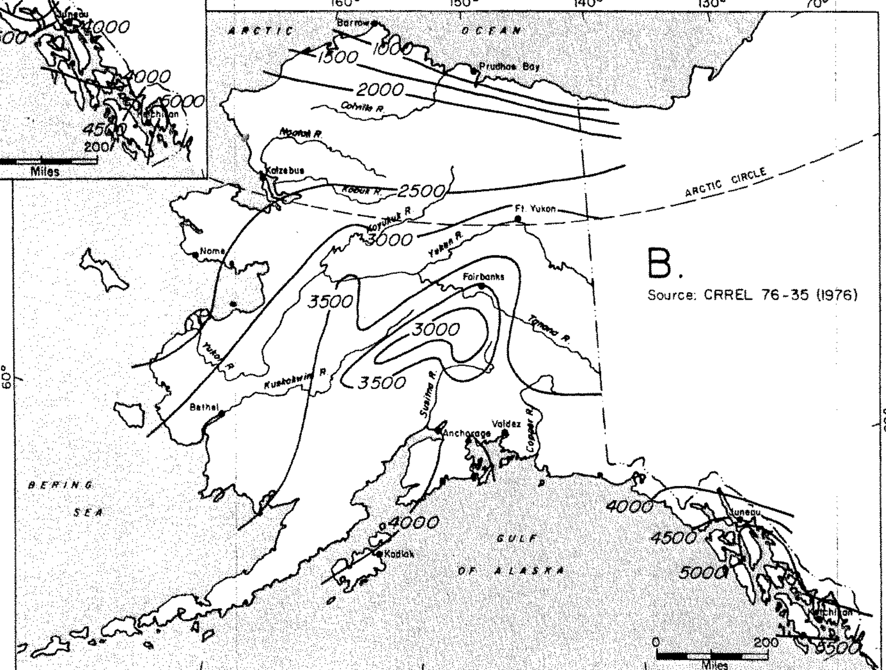
APPENDIX F

Alaska Environmental Atlas, 1984, Plate 35



A. Thawing Index, Alaska

B. Design Thawing Index, Alaska



Note:

DATA IS GENERALLY FROM LOW-LYING COASTAL AND RIVER VALLEY AREAS. IT IS PROBABLY NOT VALID FOR HIGHER ELEVATIONS.

PLATE 35

APPENDIX G

Important Information About Your Geotechnical/Environmental Report

Date: September 2005
To: Tryck Nyman Hayes, Inc.
Re: Geotechnical Investigation, Potential Relocation Sites, Kivalina, Alaska

Important Information About Your Geotechnical/Environmental Report

CONSULTING SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES AND FOR SPECIFIC CLIENTS.

Consultants prepare reports to meet the specific needs of specific individuals. A report prepared for a civil engineer may not be adequate for a construction contractor or even another civil engineer. Unless indicated otherwise, your consultant prepared your report expressly for you and expressly for the purposes you indicated. No one other than you should apply this report for its intended purpose without first conferring with the consultant. No party should apply this report for any purpose other than that originally contemplated without first conferring with the consultant.

THE CONSULTANT'S REPORT IS BASED ON PROJECT-SPECIFIC FACTORS.

A geotechnical/environmental report is based on a subsurface exploration plan designed to consider a unique set of project-specific factors. Depending on the project, these may include: the general nature of the structure and property involved; its size and configuration; its historical use and practice; the location of the structure on the site and its orientation; other improvements such as access roads, parking lots, and underground utilities; and the additional risk created by scope-of-service limitations imposed by the client. To help avoid costly problems, ask the consultant to evaluate how any factors that change subsequent to the date of the report may affect the recommendations. Unless your consultant indicates otherwise, your report should not be used: (1) when the nature of the proposed project is changed (for example, if an office building will be erected instead of a parking garage, or if a refrigerated warehouse will be built instead of an unrefrigerated one, or chemicals are discovered on or near the site); (2) when the size, elevation, or configuration of the proposed project is altered; (3) when the location or orientation of the proposed project is modified; (4) when there is a change of ownership; or (5) for application to an adjacent site. Consultants cannot accept responsibility for problems that may occur if they are not consulted after factors which were considered in the development of the report have changed.

SUBSURFACE CONDITIONS CAN CHANGE.

Subsurface conditions may be affected as a result of natural processes or human activity. Because a geotechnical/environmental report is based on conditions that existed at the time of subsurface exploration, construction decisions should not be based on a report whose adequacy may have been affected by time. Ask the consultant to advise if additional tests are desirable before construction starts; for example, groundwater conditions commonly vary seasonally.

Construction operations at or adjacent to the site and natural events such as floods, earthquakes, or groundwater fluctuations may also affect subsurface conditions and, thus, the continuing adequacy of a geotechnical/environmental report. The consultant should be kept apprised of any such events, and should be consulted to determine if additional tests are necessary.

MOST RECOMMENDATIONS ARE PROFESSIONAL JUDGMENTS.

Site exploration and testing identifies actual surface and subsurface conditions only at those points where samples are taken. The data were extrapolated by your consultant, who then applied judgment to render an opinion about overall subsurface conditions. The actual interface between materials may be far more gradual or abrupt than your report indicates. Actual conditions in areas not sampled may differ from those predicted in your report. While nothing can be done to prevent such situations, you and your consultant can work together to help reduce their impacts. Retaining your consultant to observe subsurface construction operations can be particularly beneficial in this respect.

A REPORT'S CONCLUSIONS ARE PRELIMINARY.

The conclusions contained in your consultant's report are preliminary because they must be based on the assumption that conditions revealed through selective exploratory sampling are indicative of actual conditions throughout a site. Actual subsurface conditions can be discerned only during earthwork; therefore, you should retain your consultant to observe actual conditions and to provide conclusions. Only the consultant who prepared the report is fully familiar with the background information needed to determine whether or not the report's recommendations based on those conclusions are valid and whether or not the contractor is abiding by applicable recommendations. The consultant who developed your report cannot assume responsibility or liability for the adequacy of the report's recommendations if another party is retained to observe construction.

THE CONSULTANT'S REPORT IS SUBJECT TO MISINTERPRETATION.

Costly problems can occur when other design professionals develop their plans based on misinterpretation of a geotechnical/ environmental report. To help avoid these problems, the consultant should be retained to work with other project design professionals to explain relevant geotechnical, geological, hydrogeological, and environmental findings, and to review the adequacy of their plans and specifications relative to these issues.

BORING LOGS AND/OR MONITORING WELL DATA SHOULD NOT BE SEPARATED FROM THE REPORT.

Final boring logs developed by the consultant are based upon interpretation of field logs (assembled by site personnel), field test results, and laboratory and/or office evaluation of field samples and data. Only final boring logs and data are customarily included in geotechnical/environmental reports. These final logs should not, under any circumstances, be redrawn for inclusion in architectural or other design drawings, because drafters may commit errors or omissions in the transfer process.

To reduce the likelihood of boring log or monitoring well misinterpretation, contractors should be given ready access to the complete geotechnical engineering/environmental report prepared or authorized for their use. If access is provided only to the report prepared for you, you should advise contractors of the report's limitations, assuming that a contractor was not one of the specific persons for whom the report was prepared, and that developing construction cost estimates was not one of the specific purposes for which it was prepared. While a contractor may gain important knowledge from a report prepared for another party, the contractor should discuss the report with your consultant and perform the additional or alternative work believed necessary to obtain the data specifically appropriate for construction cost estimating purposes. Some clients hold the mistaken impression that simply disclaiming responsibility for the accuracy of subsurface information always insulates them from attendant liability. Providing the best available information to contractors helps prevent costly construction problems and the adversarial attitudes that aggravate them to a disproportionate scale.

READ RESPONSIBILITY CLAUSES CLOSELY.

Because geotechnical/environmental engineering is based extensively on judgment and opinion, it is far less exact than other design disciplines. This situation has resulted in wholly unwarranted claims being lodged against consultants. To help prevent this problem, consultants have developed a number of clauses for use in their contracts, reports and other documents. These responsibility clauses are not exculpatory clauses designed to transfer the consultant's liabilities to other parties; rather, they are definitive clauses that identify where the consultant's responsibilities begin and end. Their use helps all parties involved recognize their individual responsibilities and take appropriate action. Some of these definitive clauses are likely to appear in your report, and you are encouraged to read them closely. Your consultant will be pleased to give full and frank answers to your questions.

The preceding paragraphs are based on information provided by the
ASFE/Association of Engineering Firms Practicing in the Geosciences, Silver Spring, Maryland